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Design, Preparation and In vitro Evaluation of Ciprofloxacin Hydrochloride Floating Tablets using Irvingia Gabonensis as Biopolymer Matrix

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ABSTRACT

Irvingia gabonensis (IG) gum is a biopolymer from Dika nuts. Its aqueous dispersion forms a viscous hydrocolloid with random coil conformations and has been used as matrix for controlled drug delivery. This work investigates its use to deliver ciprofloxacin as floating tablets.

Dika nut was defatted and the IG gum chemically precipitated from aqueous dispersion was evaluated in the solid state and used in the formulation of ciprofloxacin floating tablet by wet granulation. Tablets were evaluated for buoyancy, mechanical and release properties. Tablet parameters were compared with those of other polymeric matrix-formers; guar gum, ethyl cellulose and hydroxypropyl-methyl-cellulose (HPMC). The obtained data were presented as descriptive statistics and compared using selected release kinetics and swelling kinetic models.

Findings showed that IG gum had a yield of 15.2 % w/w, pH of 4.3, and a viscosity of 200 mPas. Matrix tablets of IG gum (F1) had floating lag time (FLT) of 4.5 seconds but total floating time was 24 hours. F4 (tablets with guar gum) however had an FLT of about 3 minutes. F1 followed a zero order release kinetics with a t_{90} of 7.8 hours, F3 and F4 (tablets with ethylcellulose and guar gum respectively) were best described by the Higuchi kinetic model. Only F2 (tablets with HPMC) had drug content left at the 12th hour of dissolution studies releasing only about 80% drug. *Irvingia* gum showed good potential for floating tablet matrix. With formulation optimization, the IG biopolymer will find usefulness in modified drug delivery.

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Introduction

Orally administered anti-infectives with poor solubility in the intestinal fluid can be developed as prolonged gastroenteric delivery systems to enhance bioavailability and improve patient adherence [1]. The floating matrix delivery system, also referred to as the gastroretentive delivery system is an innovative modified delivery strategy for sustained, prolonged and

extended drug release. It helps attain predictable drug release kinetics, enhances drug absorption in the gastrointestinal tract so as to achieve good therapeutic outcome [2]. As with other modified delivery strategies, the gastroretentive delivery helps to overcome fluctuations in drug plasma concentration common with conventional dosage forms, discouraging frequent dosing but improves patients' convenience and adherence. Moreover, it overcomes the common

challenge of variable gastric transit and emptying time that limits other modified release formulations. It is ideal for drugs having poor solubility- especially in low pH environment, for drugs having local activity in the stomach or readily degraded in the intestinal pH [3].

Achieving a floating delivery *in vivo*, however, can be challenging. It requires developing a dosage form that is not trapped within the overwhelming mass of gastric content (obtainable in fed state) that attempts to bury the drug during peristalsis, it requires large volume of gastric fluid but also maintaining of a good gastric transition time during drug content release. Such requirements, which are met by the floating matrix, could be assessed *in vitro* by using parameters such as floating lag time (preferably a few seconds), buoyancy and total floating time of the formulated tablets.

There have been renewed interest in the use of natural gums (biopolymers) for drug delivery in recent years, largely driven by growing concerns regarding the toxicity, cost, and limited biocompatibility of some synthetic polymers. Although it can be argued that biopolymers may be limited in availability in commercial quantities (even though this can be improved), their unique properties give them high functionality and use [4]. For example, the bioadhesiveness of biopolymers to the mucus layer give them an advantage in overcoming rapid gastric emptying that can impede floating tablets [5]. *Irvingia gabonensis* (IG) gum is a biopolymer from the seed of the fruit of the plant African mango or Bush mango. The plant is a tree that is well distributed in Africa [6]. The seeds of IG fruit, also called Dika nut, (Figure 1) is widely used in food (as a thickening agent in soups), cosmetics and the pharmaceutical space, and is reported to contain mainly polymeric constituents and lipids [7-10].

Phytochemical screening of the aqueous extract of the plant reveals that it contains high amounts of alkaloids and flavonoids but moderate quantity of cardiac glycosides and terpenoids [11]. The proximate analysis of the powdered mass of the seed has been reported to contain, in percentage weight per weight, 68.8 of fat, 4.4 crude fiber, ash content 8.1, protein 7.4 and 3.2 moisture.



Figure 1: Seeds of *Irvingia gabonensis* (Dika nuts)

The mucilage from the seed has been used as a binding agent in tablet formulations [8,9] and as an emulsifying and suspending agent in pharmaceutical preparations forming stable emulsions that compares favorably with tragacanth gum at a concentration of up to 2% w/v [12,13]. Despite these pharmaceutical applications of IG biopolymer in pharmaceutical formulations, the authors found out in their search that the gum is yet to be reported in gastroretentive drug delivery. Thus, in this work, this gum will be employed as matrix in oral floating tablet to deliver ciprofloxacin.

Ciprofloxacin is a second-generation fluoroquinolone antibiotic, placed in class II biopharmaceutics of drug classification for its poor solubility but high permeability. It possesses about 70% bioavailability, achieves rapid plasma concentration in about 1-2 hours and has an elimination half-life of 3- 4 hours [14]. In a modified oral formulation, the bioavailability of ciprofloxacin could be improved when it is delivered in a controlled fashion into the duodenum at a rate that does not exceed the maximum rate of absorption. Ciprofloxacin hydrochloride is thus ideal for this delivery strategy so that its floating tablets release will be sustained in the stomach for a prolonged period of time to optimize the drug exposure to its site of absorption. This ciprofloxacin formulation as a floating tablet would thus enhance absorption, improve bioavailability and facilitate local drug delivery to the stomach. Although ciprofloxacin has been previously prepared as floating microspheres using different polymers blends, floating multi-unit alginate beads and as floating matrix tablets [14-17], this work sought to formulate and evaluate ciprofloxacin hydrochloride as oral floating tablet using IG biopolymer as the matrix former. Based on the analysis of the available literature, this appears to be the first reported application of the IG biopolymer in a floating tablet formulation.

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Materials and Methods

IG seeds were obtained from the local market. Ciprofloxacin powder (Hopkin and William Stanheat, Essex England), Ethyl cellulose (Riedel De Haenac Seelze Hannover, China), Hydroxylpropylmethyl cellulose (Riedel De Haenac Seelze Hannover, China), Lactose (Riedel De Haenac Seelze, Hannover, China), and Guar gum (Riedel De Haenac Seelze Hannover, China) were all purchased from the local agents of the stated companies. All other reagents in use were of analar grade.

Collection of IG seeds and Defatting

The IG seeds were bought at Akpan Andem market in Uyo, the capital of Akwa Ibom State, a South-South region of Nigeria, on the 7th February, 2022. The seeds were identified and authenticated in the Department of Pharmacognosy and Natural Medicine, Faculty of Pharmacy, University of Uyo, Nigeria.

Exactly 300 g of the weighed seed (Ohaus digital balance, Galaxy) was pulverized using an electric

blender to improve the surface area before gum extraction. Since the powder mass has high content of lipid, it was necessary the lipid is removed so as not to interfere with the solid-state characterisation and properties of the gum. To remove the fat, the powder mass was placed in the thimble of the Soxhlet apparatus and 500 mL of n-hexane added unto the round bottom flask assembled in Soxhlet apparatus and heating mantle set at 60 °C. The residue after decanting was then dried in the laboratory hot-air oven (TT-9053, Techmel Techmel, USA) at 60°C for 1hr.

Extraction of IG gum

The defatted dried powder mass (50 g) was weighed out and dispersed in 450 mL of hot distilled water for 45 minutes. The dispersion was then screened through a muslin cloth to obtain a mucillagenous filtrate. The IG gum was then precipitated out from the filtrate using a mixture of ethanol and acetone solvents in equal volume ratio to give a faster and possibly greater yield. The precipitate was filtered and then allowed to dry in the oven at 60°C for 1 hr. Figure 2 shows a flow chart for biopolymer extraction.

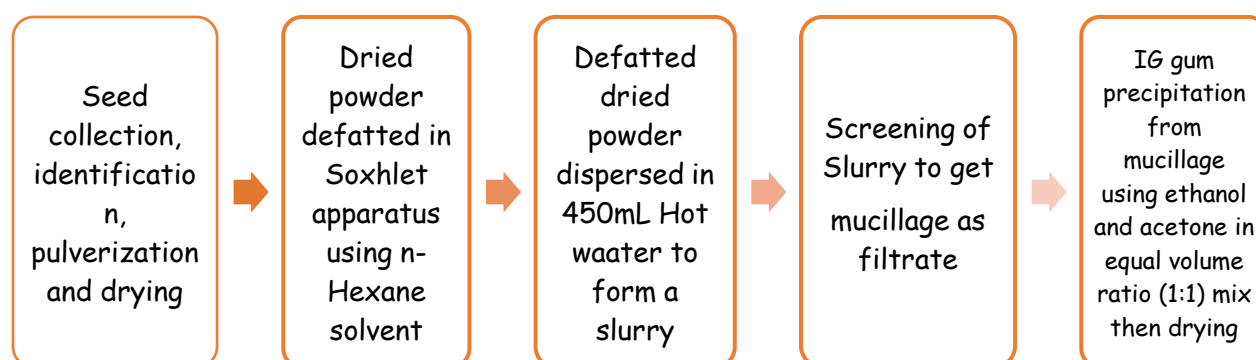


Figure 2: Flow chart of showing IG gum extraction from the seeds

Gum Characterization

Physicochemical characterization

The IG gum was evaluated for physical characteristics such as appearance, odour, moisture content, pH value, solubility, swelling capacity, and viscosity using procedures as described in Effiong and colleagues (2024a) [18], while the micromeritics and the water holding (hydration) capacity of the gum were also carried out as described by Effiong and coworkers (2024b) [19]. Same procedures were followed to evaluate for the three other polymers used to compare the IG biopolymer. The chemical tests of Ruthenium red

test and aqueous KOH test were used to confirm presence of the gum in the powdered precipitate [20].

Preparation and evaluation of granules

Four batches of granules were prepared to give 50 tablets, each tablet being 500mg by weight. Each batch was made of a different matrix former and thus the four batches had *Irvingia gabonensis* gum, hydroxylpropylmethyl cellulose, guar and ethyl cellulose respectively for the granules and subsequently, the tablets. The wet granulation method was employed (with each biopolymer incorporated as granulation fluid) so as to minimize creation of charges during processing. The granulating fluid was prepared

using the matrix former and 95% ethanol to facilitate rapid drying and prevent a premature reaction between granule components (citric acid and sodium

bicarbonate). The formula for the composition of each batch is presented in table 1.

Table 1: Composition of ciprofloxacin floating tablet batches.

Ingredients	F1	F2	F3	F4
Ciprofloxacin Hydrochloride	250	250	250	250
<i>Irvingia gabonensis</i> (%)	20	-	-	-
HPMC (%)	-	20	-	-
Ethyl cellulose (%)	-	-	20	-
Guar gum (%)	-	-	-	20
Sodium bicarbonate (mg)	10	10	10	10
Citric acid (mg)	5	5	5	5
Lactose	qs	qs	qs	qs
Total weight to (mg)	500	500	500	500

Preparation and evaluation of granule properties

Preparation of tablets

Each batch of the prepared granules was properly mixed with magnesium stearate and talc as lubricant and anti-adherent respectively, then fed into a single punch tableting machine (Cadmach, Ahmedabad, India) for compression force of 15kN to produce four batches (each batch consisting of 50 tablets and each tablet being 500 mg) with a good tensile strength.

Tablet evaluation

Prepared tablets were evaluated for mechanical properties (weight uniformity, hardness, friability, tablet dimensions and tensile strength) using standard methods as reported by Effiong and co-researchers (2024b) [19] to ascertain if they meet the standards as set in official compendium.

Swelling kinetics

The swelling study of the tablets in each batch was performed focusing on the change in weight of the tablet in 0.1 N HCl medium using method described by Arza and colleagues with some modifications [14]. After an initial weight(w_1) of individual tablet was taken, it was placed in a petri dish to which about 15 mL of 0.1N HCl was filled. The tablet was removed, weights were taken then returned, at intervals of 30 minutes for 8 hours. For each of the subsequent weights (w_2 at each specific time), the tablets were wiped off gently to remove

excess media and percentage hydration (swelling index) at each time was calculated using the formula:

$$\text{Swelling Index} = \frac{w_2 - w_1}{w_1} \times 100 \quad \text{Equation 1}$$

Where, w_1 is the initial weight of tablet and w_2 is the weight of hydrated tablet at each time.

Also, the data from swelling studies were fitted to the Vergnaud model for swelling studies to determine the swelling constant and rate for each of the biopolymer

In vitro Buoyancy studies

The floating characteristic of the tablet was investigated using the method in the authors' earlier work [20]. The floating lag time and the total floating time were determined by visual observation with respect to time. The time for tablet introduced into the aqueous medium (0.1N HCl) to move from the bottom of the beaker to the surface was taken as the floating lag time while the total duration it stayed on the surface was the total floating time

Standard Calibration Curve for Ciprofloxacin

A 0.5 mg quantity of ciprofloxacin powder was dissolved in 10 mL of the dissolution medium (simulated gastric fluid [SGF]). The resultant solution was placed in a beaker. Also, a small quantity of each medium was labeled as the blank. Serial dilutions of 1-5 mcg/mL were prepared and their absorbance were

read in a spectrophotometer (UNICO-spectrophotometer, UV-2100PC Shanghai instrument Co. Ltd, China) at a wavelength of 273 nm. Plots of absorbance versus concentration were generated from data obtained using excel spreadsheet (Microsoft incorporation) to obtain the calibration curve of Ciprofloxacin in simulated gastric fluids.

In vitro dissolution study

The *in-vitro* release rate of ciprofloxacin hydrochloride tablet was determined using the USP basket-type dissolution apparatus, (RCZ-6C3 Type Medicine Dissolving Instrument, China) after a calibration curve for the ciprofloxacin powder was first determined. Each tablet was placed in a cylindrical basket of stainless-steel wire mesh attached to a rotor and immersed in a

hemispherical cylinder containing 900 mL of 0.1 N HCl dissolution medium. The medium was maintained at temperature $37 \pm 1^\circ\text{C}$ and rotation speed of 100 revolutions per minute (rpm) by means of a heating unit within the apparatus and the regulated rotor respectively. Exactly 10 mL of the dissolution medium was withdrawn and simultaneously replaced with a fresh dissolution medium at regular intervals of 30 minutes up to 12 hours to maintain a sink condition. The withdrawn samples were filtered through a Whatman filter paper no.2, diluted with a blank dissolution medium (two-fold dilution) and the absorbance of the solution determined at 273 nm using spectrophotometer (UNICO-spectrometer, UV-2100PC Shanghai instrument Co. Ltd, China). The concentration (and amount) of the drug released at different time interval was determined when the read absorbances were compared with the calibration curve earlier established.

Table 2: Physicochemical and micromeritic properties of the gums (Mean $\pm$ s.d, n=3).

Parameters	Polymer powders			
	<i>I. gabonensis gum</i>	HPMC	Ethyl cellulose	Guar gum
Appearance	Brown	White	White	Off White
Odour	Odourless	Odourless	Odourless	Odourless
Solubility	Soluble in water Insoluble in ethanol	Soluble in water Insoluble in ethanol	Insoluble in water soluble in ethanol	Soluble in water Insoluble in ethanol
Water holding capacity (g/g)	0.50 $\pm$ 0.01	0.18 $\pm$ 0.01	0.93 $\pm$ 0.01	0.71 $\pm$ 0.01
Swelling capacity (%)	4.60 $\pm$ 0.17	2.80 $\pm$ 0.04	4.59 $\pm$ 0.08	2.40 $\pm$ 0.12
Moisture (%)	7.40 $\pm$ 0.20	11.09 $\pm$ 0.30	8.34 $\pm$ 0.21	14.09 $\pm$ 0.20
Viscosity (mPas)	200	478.6	611	621
Bulk density (gcm ⁻³)	0.29 $\pm$ 0.07	0.47 $\pm$ 0.00	0.47 $\pm$ 0.00	0.43 $\pm$ 0.00
Tapped density (gcm ⁻³)	0.37 $\pm$ 0.00	0.67 $\pm$ 0.00	0.63 $\pm$ 0.00	0.69 $\pm$ 0.02
Hausner's ratio	1.28 $\pm$ 0.02	1.43 $\pm$ 0.00	1.34 $\pm$ 0.00	1.60 $\pm$ 0.03
Carr's Index	21.62 $\pm$ 0.00	29.85 $\pm$ 0.00	25.40 $\pm$ 0.00	37.68 $\pm$ 2.31
Flow rate (g/s)	3.02 $\pm$ 0.32	1.23 $\pm$ 0.07	5.99 $\pm$ 1.01	0.69 $\pm$ 0.00
Angle of repose ($^\circ$)	28.50 $\pm$ 1.36	32.91 $\pm$ 1.02	28.30 $\pm$ 1.58	38.80 $\pm$ 1.20
pH value	4.30 $\pm$ 0.00	6.85 $\pm$ 0.02	5.80 $\pm$ 0.00	7.02 $\pm$ 0.01

Release kinetics and dynamics

The drug release data obtained at different times were fitted into release kinetics equation models of zero order ($Q=kt$), first order ($\ln Q_t = \ln Q - kt$), Higuchi ($Q=kt^{1/2}$) and Korsemeyer Peppas ($Q_t/Q_\infty = kt^n$) in order to determine which one best describes the drug release pattern by using the highest value of the

regression coefficient of model for each batch and the mechanism of drug release respectively. In addition, the pharmacokinetic parameters like time at 50% percentage drug dissolution (t_{50}) and time at 90% drug dissolution (t_{90}) were used to compare the drug release from the different biopolymers

Statistical analysis

The results were presented in statistical formats as mean $\pm$ standard deviation. Results for swelling studies of the floating tablets and their release kinetics were subjected to One-way Analysis of Variance (ANOVA) using the social science statistics online app (www.socscistatistics.com) to indicate differences between the polymer samples. Where significant differences were observed, a post hoc Turkey HSD test with $P < 5\%$ considered significant for pairwise comparison.

Results

The physicochemical and micromeritic properties of *Irvingia gabonensis* and the other biopolymers compared with it are presented in Table 2 while properties of their granules are in Table 3. Although

ethyl cellulose is insoluble in aqueous medium, unlike other biopolymers, it exhibited the highest water hydration capacity. Also, in terms of powder characteristics, it showed the highest flow rate of 5.99g/s. The IG polymer, on the other hand, exhibited an intermediate flow rate—between the highest and the lowest values. Based on these results, the biopolymers can be ranked as follows in terms of flow properties: Ethyl cellulose > IG gum > HPMC > Guar gum.

Generally, the flow properties of the granule improved when compared with those of the gums (Table 3). Granulation enhances flowability of powders. The F1 granules had the highest porosity while F4 had the least, indicating how the particles are arranged in the granule mass.

Table 3: Flow properties of ciprofloxacin granules of the different gums (Mean $\pm$ s.d, n=3).

Parameters	Batch formulations			
	F1	F2	F3	F4
Flow rate (g/s)	6.40 $\pm$ 0.19	5.13 $\pm$ 0.71	4.00 $\pm$ 0.16	4.50 $\pm$ 0.34
Angle of Repose ($^\circ$)	24.20 $\pm$ 0.50	25.60 $\pm$ 2.98	30.42 $\pm$ 0.29	28.90 $\pm$ 3.30
Bulk Density (g/cm ³)	0.40 $\pm$ 0.01	0.48 $\pm$ 0.03	0.38 $\pm$ 0.01	0.49 $\pm$ 0.01
Tapped Density (g/cm ³)	0.54 $\pm$ 0.03	0.65 $\pm$ 0.02	0.48 $\pm$ 0.03	0.72 $\pm$ 0.05
Hausner's Ratio	1.35 $\pm$ 0.06	1.35 $\pm$ 0.02	1.26 $\pm$ 0.45	1.46 $\pm$ 0.08
Carr's Index	25.90 $\pm$ 2.8	26.15 $\pm$ 3.14	20.80 $\pm$ 3.10	31.94 $\pm$ 3.79
True density (g/cm ³)	1.50 $\pm$ 0.12	1.60 $\pm$ 0.10	1.35 $\pm$ 0.10	1.31 $\pm$ 0.11
Packing fraction	0.27 $\pm$ 0.03	0.30 $\pm$ 0.01	0.28 $\pm$ 0.03	0.37 $\pm$ 0.04
Granule porosity	73.00 $\pm$ 8.80	70.00 $\pm$ 2.21	72.00 $\pm$ 7.24	63.00 $\pm$ 6.96
F1 are ciprofloxacin granules of <i>Irvingia gabonensis</i> , F2 drug granules with HPMC, F3 is drug granules of Ethylcellulose and F4 drug granules of Guar gum.				

Table 4: Physico-mechanical properties and buoyancy of ciprofloxacin floating tablets containing test biopolymers (Mean $\pm$ SD, n=3, but for friability n=5 but for weight, thickness and diameter n=20).

Formula tion Batches	Friability (%)	Hardness (KgF)	Tablet weight (g)	Tablet thickness (mm)	Tablet diameter (mm)	Compact density (gcm ⁻³)	Tensile strength (MNm ⁻²)	Tablet porosity (%)
F1	0.10 $\pm$ 0.01	6.82 $\pm$ 0.27	0.52 $\pm$ 0.01	3.00 $\pm$ 0.00	12.64 $\pm$ 0.01	1.38 $\pm$ 0.03	1.15 $\pm$ 0.31	8.00
F2	0.33 $\pm$ 0.04	6.40 $\pm$ 0.42	0.51 $\pm$ 0.01	3.10 $\pm$ 0.21	12.62 $\pm$ 0.01	1.32 $\pm$ 0.28	1.04 $\pm$ 0.47	18.00
F3	0.62 $\pm$ 0.12	6.40 $\pm$ 0.42	0.50 $\pm$ 0.03	3.00 $\pm$ 0.00	12.61 $\pm$ 0.01	1.33 $\pm$ 0.03	1.08 $\pm$ 0.45	2.00
F4	0.30 $\pm$ 0.09	4.90 $\pm$ 0.42	0.52 $\pm$ 0.02	3.00 $\pm$ 0.01	12.65 $\pm$ 0.03	1.38 $\pm$ 0.05	0.82 $\pm$ 0.34	37.00

F1 are tablets with *Irvingia gabonensis*, F2 tablets with HPMC, F3 is batch of tablets with Ethylcellulose and F4 is tablet batch with Guar gum.

The mechanical properties, buoyancy and swelling component of the formulated tablet batches are

presented in Tables 4 and 5. No batch of the formulated tablets lost up to 1% of its weight on subjecting it to the

friability test, hence they all passed the test while also maintaining a good crushing strength (hardness) in the range 4.90-6.82 kgf and tensile strength 0.82-1.15 MNm⁻². The buoyancy of the formulated tablet showed

good onset of floating in the range of 4.50-150s and the time of floating being >24hour (for F2 and F4) but 24 hours or less (F1 and F4) as shown in table 5

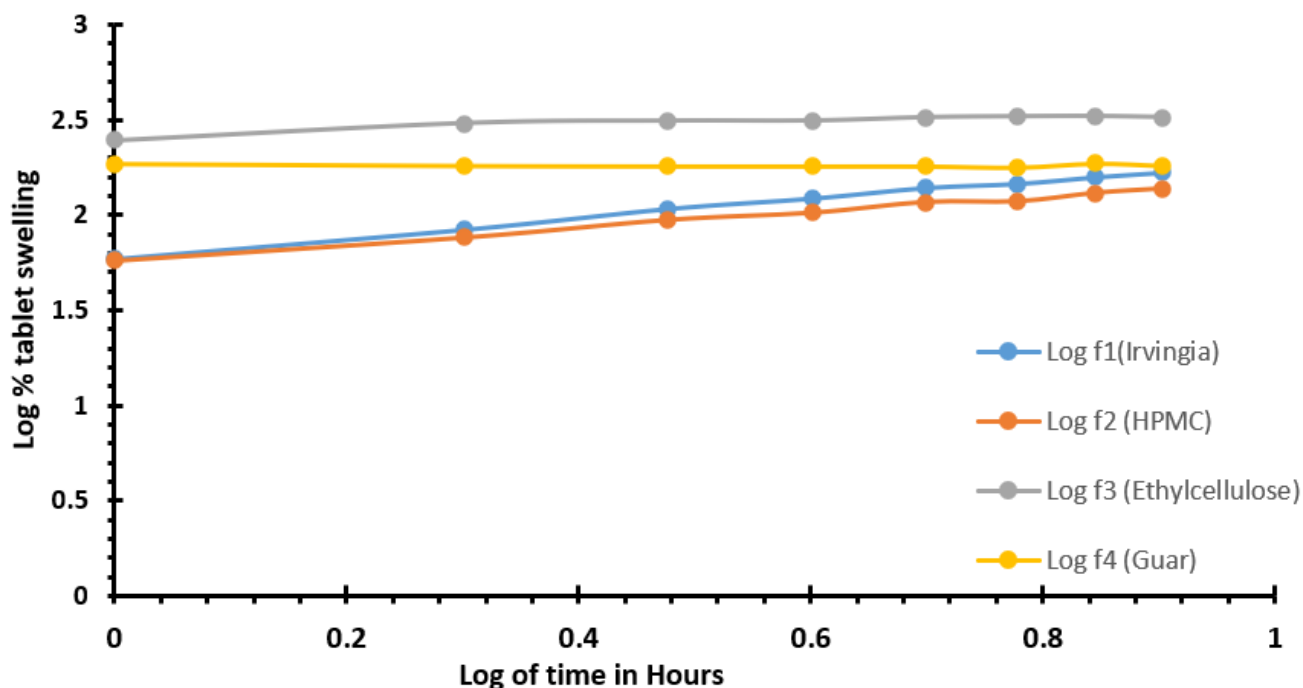


Figure 3: Log of percentage tablet swelling against the Log of time.

Table 5: Buoyancy properties of ciprofloxacin floating tablets containing test biopolymers (Mean± s.d, n=3).

Formulation Batches	Floating lag time (s)	Total floating time (hour)	Swelling component (n)	Swelling rate (hour ⁻¹)
F1 (containing IG)	4.50 ± 0.71	24	0.50	60.00
F2 (containing HPMC)	125.00 ± 0.07	>24	0.41	58.28
F3 (containing Ethylcellulose)	45.00 ± 21.21	12	0.12	262.30
F4 (containing Guar)	150.00 ± 14.14	>24	0.01	184.29

The swelling kinetics of the floating tablets using different polymers according to the Vergnaud model is presented in Figure 3.

Figures 4 and 5 show the water uptake of the formulated tablets over time and the percentage cumulative drug release in the in vitro dissolution medium, respectively. The drug release kinetics and dynamics from the dissolution studies are presented in Table 5.

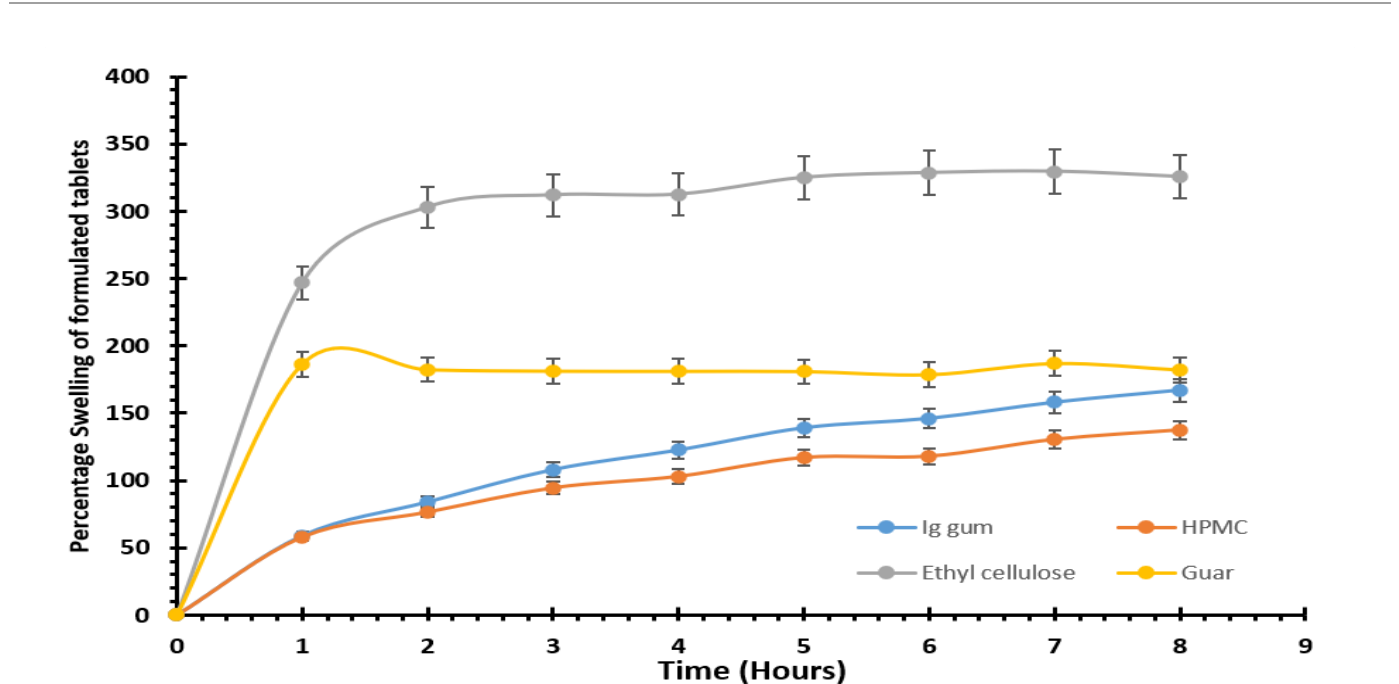


Figure 4: Swelling of floating tablets over time

Table 6: Release kinetics and mechanism of the floating tablets and time for 50% and 90% release.

Batches	Regression Coefficient of kinetic plots (R ²)					t ₅₀ (Hours)	t ₉₀ (Hours)
	Zero order	First order	Higuchi model	Korsemeyer Peppas			
				R ²	Diffusion coefficient (n)		
F1	0.936	0.862	0.883	0.833	0.63	5.75	7.80
F2	0.961	0.979	0.977	0.924	0.45	5.85	>12
F3	0.952	0.924	0.962	0.883	0.39	4.30	11.20
F4	0.798	0.883	0.928	0.903	0.26	0.41	6.80

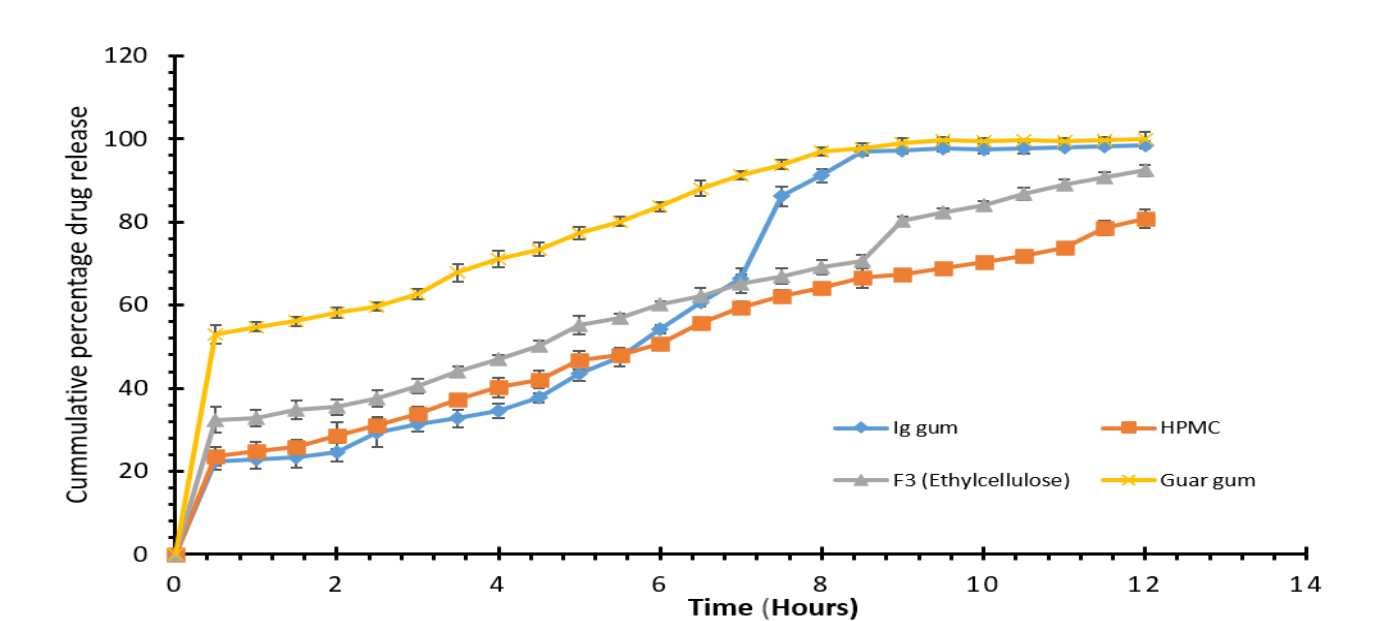


Figure 5: In vitro cumulative drug release profile of the formulated floating tablet.

Discussion

The micromeritics of the dried powdered gum from *Irvingia gabonensis* seeds showed it had a good flow. The values of the densities, flow rates, angle of repose and the compressibility index obtained for the gum is approximately the same as those earlier reported by Shittu and Njinga [21]. The pH of the gum is acidic. This also corroborates what was earlier reported by Shittu and Njinga [21]. While they reported the pH value to be 6, using 1g of the gum in 120 mL of distilled water, in this work, 1%w/v of the seed gum dispersion was used and the pH was determined to be 4.3. This difference in concentration of the aqueous gum dispersion is likely responsible for the variation in the results.

The physico-mechanical properties of the tablets formed met the compendial standards. All the batches of formulated tablets passed the friability test, by showing < 1% loss of tablet weight, hardness test of 4-8kgf and had a good tensile strength (see Table 4) [22]. Also, there seems to be a correlation between the porosity of the tablet and the tensile strength, porosity being a pointer as to what extent fluid can be uptaken in the tablet matrix to bring about swelling reaction and drug release.

The floating of the tablets is based on the generation of carbon dioxide gas from the reaction of citric acid and sodium bicarbonate components embedded within the tablet, as fluid from the aqueous acidic environment gets absorbed in tablet matrix. As the generated gas gets entrapped within the wet swollen tablet matrix, it reduces the tablet density thereby making it to float [14]. How rapidly floating occurs is described by the floating lag time and is influenced by rate at which the dissolution medium penetrates the tablet matrix, the amount and rate of the gas generated within the tablet [17, 23]. Sodium bicarbonate has been reported to rapidly generate carbondioxide gas faster than sodium carbonate, hence the choice in this work [5]. Since the different batches of tablets had the same composition except for the type of matrix former (biopolymer) used, it could be inferred that the resulting variation in the floating lag time of the formulations (between 4s and 150s), is polymer-type dependent. F1 tablet (containing 20% IG gum) had the least floating lag time while that of F4 (containing 20% guar gum) was the highest. Hence, the tablets could be ranked on the basis of onset of floating as F1>F3>F2>F4. Such polymer dependent difference in the lag time is influenced by the variation in the swelling properties (e.g., early onset of swelling and swelling rate constant) and mechanisms of the

polymer interaction in the aqueous environment [14]. Furthermore, it appears that the onset of swelling, the swelling component and the tablet porosity influenced floating lag time and the total floating time.

The degree of swelling of a hydrophilic biopolymer is a key parameter evaluated in controlled drug release because it indicates the diffusion rate of penetrants (the dissolution media) into polymer matrix and drug movement within the gel of the wet biopolymer [24, 25]. It can also reveal the structure of the biopolymer and its drug release behaviour. This degree of swelling and how rapidly it occurs could be monitored using the change in the dimensions of the tablet formed with the biopolymer, the change in weight or the rate of liquid uptake [14, 26]. In this work, the percentage change in weight was used. Although F3 and F4 achieved very high mean percentage swelling (247% and 186% respectively) in the first 1 hour then remained almost constant subsequently, F1 and F2 had gradual increase in swelling over time. This likely explains the higher value for swelling component of F1 and F2 (Table 3, Figures 3 and 4). This could be that while F3 and F4 had larger mesh size of polymer network and intramolecular chains of polymer structure that initially allowed ease of liquid uptake, as the polymer gets wet and becomes a gel, those mesh sizes and chains in structure becomes constant [23, 27]. The contrast appears to be the case with F1 and F2 in which the mesh size and chain structure of the polymers gradually increased with time. The swelling kinetics studies revealed that there was a significant difference in the swelling behaviour of the polymers ($p<0.05$). The post hoc Turkey HSD shows that IG swelling behaviour was significantly different from those of Ethyl cellulose and Guar gum ($p<0.05$).

Interestingly, although porosity of the tablet influences swelling, that parameter alone (in the conditions and polymers studied) does not predict the outcome of swelling as the biopolymer (F1 and F3) with a relatively high swelling rate had a minimal porosity. Asim and colleagues (2017) had reported a similar observation in the HPMC they studied and explained that such occurrence may be due to high osmotic stress within the matrix [28]. To gain more insight into the swelling mechanism, the Vergnaud model [29] was applied (Figure 3) by fitting the swelling data into the following equation:

$$M = Kt^n \quad \text{Equation 2}$$

where M is the amount of liquid transferred at a given time,

k is the swelling rate constant, and n is the swelling exponent (component).

The value of k depends on the porosity and diffusivity of the tablet matrix as well as the amount of liquid transferred after an infinite time. When rearranged the equation becomes

$$\text{Log}M = \log K + n \log t \quad \text{Equation 3}$$

where n indicates the mechanism of swelling of the polymer.

From the swelling component determined, F2, F3 and F4 exhibited the diffusion-controlled swelling (where $n < 0.5$) with highest of the three values seen in F2. However, F1 with a swelling component ($n = 0.5$) is strictly a diffusion mediated swelling obeying Fick's law.

Drug dissolution studies and release kinetics (shown on Table 6 and Figure 5) demonstrate that the F1 formulation (tablet with 20% IG gum) could be best described by the zero order release kinetics, meaning that the release of the drug from the matrix was constant with time, irrespective of the amount of drug that was remaining in the device. One-half of the total drug content (t_{50}) was released in about 5 hours 15 minutes while 90% of the drug (t_{90}) content was released in about 7 hours. F3 and F4 followed the Higuchi's release kinetics model, that is the amount of the drug release varied with respect to the square root of time. While t_{50} for F3 (containing 20% Ethyl cellulose) was above 4 hours, for F4 (20% guar gum), it was only 25 minutes. The difference in the dissolution study of the tablets from the polymers was significant ($p < 0.05$) and the post hoc Turkey HSD ($p < 0.05$) indicates that drug release from the tablet containing IG gum was significantly different from tablets containing the other polymers; HPMC, Guar and ethyl cellulose. This may be explained in terms of their difference in the swelling properties. F4 showed higher onset of swelling and swelling capacity hence faster drug release. Formulation F2 (tablet with 20% HPMC) was best described by the first order release kinetics, where in the amount of drug release with time was dependent on the amount of drug remaining in the matrix. The t_{50} and t_{90} for F2 were the highest and aligned with the data from swelling studies, having the least swelling rate and onset of swelling (tables 5 and 6). In fact, less than 90% of F2 was let out in the 12-hour duration of the dissolution studies. This indicates the higher retentive potential of the HPMC for extended drug release delivery even though it had a poor floating lag time. Further work in optimizing a

formulation of the IG biopolymer and HPMC could give an improved gastroretentive delivery system to achieve prolonged drug release with lower floating lag time.

The mechanism of drug release, as shown in the value of diffusion coefficient in line with Korsemeyer-Peppas model for cylindrical tablets ($0.45 < n < 0.89$) on table 6 indicates most probable anomalous transport/non-Fickian diffusion for F1[25]. This implies that the drug release was governed by a combination of diffusion and polymer relaxation/erosion processes. Similar mechanism was reported by Arza and colleagues [14] who attempted the delivery of floating ciprofloxacin tablet using synthetic polymers. F2 with $n = 0.45$ is best described by the Fickian mechanism of drug release, meaning that the drug release is mainly controlled by diffusion through the polymer matrix. F3 and F4 however followed the Quasi Fickian mechanism of drug release as $n < 0.45$. This mechanism has been described as a non-swelling matrix diffusion [30].

Conclusion

Irvingia gabonensis biopolymer, used at 20% w/w in the formulation, demonstrated good potential as a matrix material for floating tablets. These tablets attained rapid floating in less than 5 seconds but sustained drug release for about 7 hours. This is due to its good swelling component. Floating tablets with ciprofloxacin formed with *Irvingia gabonensis* had good physico-mechanical properties and integrity. Further work on fine-tuning the *Irvingia* biopolymer matrix could result in improving its drug-controlled release properties for longer release (prolong release), thereby enlarging the excipient base for innovative delivery strategies.

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Conflict of Interest

None.

Author Contributions

All the authors contributed to the study.

References

1. Tomeri N., Anurag K P., Sharma A. Preparation and Evaluation of floating matrix tablet of Tolbutamide as a sustained release drug delivery system. *European Chemical bulletin*.2023; 12(9): 981-1000. DOI:10.48047/ecb/2023.12.9.97

2. Herder S, Fuhr U., Beermann D and Staib A H. Ciprofloxacin absorption in different regions of the human gastrointestinal tract. Investigations with the hf-capsule. *The British Journal of Clinical Pharmacology*. 1990;30: 35-39
3. Streubel A., Siepmann J., Bodmeier R. Floating matrix tablets based on low-density foam powder: effects of formulation and processing parameters on drug release. *Eur. J. Pharm. Sci.* 2003;18(1): 37–45
4. Chitnis V. S., Malshe V. S., Lalla J. K. Bioadhesive polymer-synthesis, evaluation and application in controlled release tablets. *Drug Dev. Ind. Pharm.* 1991; 17(6): 879–892
5. Ndiana-Abasi S, Ekpo M., Emeje M O. Evaluating Okra gum in a floating tablet formulation as a novel drug delivery system. *Pharmaceutical Technology* September. 2021;:44-49
6. Atangana A R, Ukafor V.,Anegbeh P., Asaah E, Tchoundjeu Z, Foundoun JM, et al., Domestication of *Irvingia gabonensis*:2. The selection of multiple traits for potential cultivars from Cameroun and Nigeria. *Agroforestry systems*. 2002;55: 221-229
7. Adeyeye E I., Arogundade L A., Akintayo E T., Asida O A., Alao P A. Calcium, Zinc and Phytate interrelationship in some foods of major consumption in Nigeria. *Food Chemistry*. 2000;71: 435-441
8. Odeku O A., Patani B. Evaluation of dika nut mucilage (*Irvingia gabonensis*) as a binding agent in metronidazole tablet formulation. *Pharmaceutical Development Technology*. 2005;10:439-446
9. Tairu A O., Hofmann T. Scieberie P. Studies on the key odorants formed by roasting of wild mango seeds (*Irvingia gabonensis*). *Journal of Agric food chem.* 2000; 48: 2391-4
10. Ugwu K., Ugwueke M., Ezema C G. Composition and fuel potentials of *Irvingia gabonensis*. *Trends in Applied Science Research*. 2023; 18(1):1-7
11. Mgbemena N, M., Ilechukwu I O, Kwunodolu F U., Chukwura J O and Lucky I B. Chemical composition, proximate and phytochemical analysis of *Irvingia gabonensis* and *Irvingia wombolu* peels, seed coat, leaves and seeds. *Sciend*. 2019; 30(1):65-69
12. Ndjouenkeu R, Goycoolea F.M, Morris E.R and Akingbala J.O. Rheology of okra (*Hibiscus esculentus* L.) and dika nut (*Irvingia gabonensis*) polysaccharides. *Carbohydrate Polymers*. 1996; 29: 263-269
13. Isimi C.Y, Kunle O.O and Bangudu A.B. Some emulsifying and suspending properties of the mucilage extracted from kernels of *Irvingia gabonensis*. *Boll. Chin.Farm.* 2000;139:199-204
14. Arza R A, Gonugunta C S, Veerareddy P R. Formulation and evaluation of swellable and floating gastroretentive ciprofloxacin hydrochloride tablets. *AAPS PharmSciTech.* 2009;10(1):220-6. doi: 10.1208/s12249-009-9200-y
15. Sahoo S. K., Mohapatra S., K Dhal S., Behera B. C., Barik B. B. Formulation of floating microspheres of ciprofloxacin hydrochloride by crosslinking technique. *Indian Pharm.* 2007;58(6):65–68.
16. Srinath A., Pandit J. K. Multiple-unit floating alginate system: effect of additives on ciprofloxacin release. *Drug Delivery*. 2008;15(7):471–476. doi: 10.1080/10717540802329282
17. Varshosaz J., N. Tavakoli N & Roozbahani F. Formulation and in vitro Characterization of Ciprofloxacin Floating and Bioadhesive Extended-Release Tablets. *Drug delivery*.2005;13:277-285.
18. Effiong D E., Akpabio E I. Uwah. T O. Okon U., Kaalu, M U. Salbutamol Oral Films: Design, Preparation and Evaluation Using Blends of Pectin and Mucilage of *Dioscorea alata*. *Trends in Medical Research* 2024;19 (1): 208-219. <https://doi.org/10.3923/tmr.2024.208.219>
19. Effiong D E, Udoh E, Uwah T O., Sunday N I., Jacob, G, Akpabio, E I. Preparation and Evaluation of carboxymethylated *Dioscorea bulbifera* starch as disintegrant in ibuprofen oral tablet. *Trends in Medical Research*. 2024;19 (1): 23-34. <https://doi.org/10.3923/tmr.2024.23.34>
20. Akpabio E I, Effiong D E, Uwah, T O., Sunday N I. Formulation and in vitro evaluation of Theophylline Hydrochloride effervescent floating tablet: Effect of polymer concentration on tablet buoyancy. *International Journal of Pharmacy and Pharmaceutical Sciences*.2020;12(1):59-65. doi.org/10.22159/ijpps2020vi1.35055
21. Shittu, A. O. and Njinga, N. S. Isolation and Characterization of *Irvingia gabonensis* Seed contents and the Tableting Properties of its Gum Component. *Dhaka Univ. J. Pharm. Sci.* 2024; 23(1): 53-62
22. W. Lund. *The Pharmaceutical Codex: Principle and Practice of Pharmaceutics*. Pharmaceutical Press, London (12th Edition). 1994: 987– 992.
23. Carbinatto, F M de Castro, A D, Evangelista, R C and Cury BSF. Insights into the swelling process and drug release mechanisms from cross-linked pectin/high amylose starch matrices. *Asian Journal of Pharmaceutical Sciences* 2014; 9 (2014):27-34. <http://dx.doi.org/10.1016/j.ajps.2013.12.002>

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24. Yin YH, Yang YJ, Xu HB. Swelling behavior of hydrogels for colon-site drug delivery. *Journal of Applied Polymer Science*. 2002; 83:2835-2842.
25. Sriamornsak P, Thirawong N, Weerapol Y, Nunthanid J, Sungthongjeen S. Swelling and erosion of pectin matrix tablets and their impact on drug release behavior. *Eur J Pharm Biopharm*. 2007;67(1):211-9. doi: 10.1016/j.ejpb.2006.12.014. Epub 2006 Dec 28. PMID: 17267193.
26. Gerogiannis V S, Rekkas D M, Dallas P P, Choulis N H. Floating and swelling characteristics of various excipients used in controlled release technology. *Drug Development and Industrial Pharmacy*.1993; 19(9):1061-1081. doi:10.3109/03639049309063001
27. Cury BS, Castro AD, Klein SI, Evangelista RC. Modeling a system of phosphated cross-linked high amylose for controlled drug release. Part 2: physical parameters, cross-linking degrees and drug delivery relationships. *Int J Pharm*. 2009;371(1-2):8-15. doi: 10.1016/j.ijpharm.2008.12.010. Epub 2008 Dec 13. PMID: 19124066.
28. Asim M S, Ghori M U, Conway, B R. Probing the Impact of Porosity on swelling kinetics of hydrophilic matrices. *British Journal of Pharmacy*. 2017;2(2):511-513. Doi.org/10.5920/bjpharm.2017.16
29. Vergnaud J M. Liquid transport-controlled release processes in polymeric materials: applications to oral dosage forms. *International Journal of Pharmacy*. 1993;90(2):89-94
30. Preethy A J, Paarakh M P, Setty C M, Christopher GVP. Release Kinetics- Concepts and Application *International journal of Pharmacy research and technology*. 2018;8:12-20.

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