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Formulation and Evaluation of Floating Tablets of Model Drug

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Abstract: *Pre-formulation studies are essential in pharmaceutical development to understand the physical and chemical properties of a drug and its interactions with excipients. This study focuses on the pre-formulation investigations of Nifedipine to develop suitable dosage forms for therapeutic purposes. Standard solutions of Nifedipine were prepared, and calibration curves were generated using UV double beam spectrophotometry. Drug-excipient compatibility was evaluated using FTIR spectroscopy. Floating tablets of Nifedipine were formulated using various polymers via direct compression method. The pre-compression and post-compression parameters of the formulated tablets were evaluated, including bulk density, tapped density, compressibility index, Hausner's ratio, angle of repose, hardness, friability, drug content, and buoyancy studies. In-vitro dissolution studies were conducted using USP-II apparatus. The standard calibration curve of Nifedipine showed a linear relationship between concentration and absorbance. FTIR studies indicated compatibility between the drug and excipients. Evaluation of pre-compression parameters revealed variations among formulations. Post-compression parameters demonstrated uniformity in tablet weight, mechanical strength, and drug content. Buoyancy studies showed variation in floating properties among formulations. Swelling index studies revealed hydration kinetics of tablets. Dissolution studies depicted drug release profiles over time. Kinetic modelling revealed that the optimized formulation followed Higuchi release kinetics, indicating diffusion-controlled drug release. Stability studies of the optimized formulation (F5) showed consistent thickness, hardness, and drug content over a period of three months, indicating formulation stability. This comprehensive study provides insights into the pre-formulation, formulation, and evaluation of floating tablets of Nifedipine, contributing to the development of gastroretentive drug delivery systems.*

Keywords: Pre-formulation, Nifedipine, Excipients, Floating tablets, Dissolution, Compatibility, Kinetic modeling, Stability.

I. INTRODUCTION

The introduction section of a research paper serves as the gateway to the study, providing essential context, rationale, and scope for the research. It sets the stage for readers by presenting the background information, highlighting the significance of the study, stating the research objectives, and outlining the structure of the paper.[1,2]

Begin by providing background information relevant to the research topic. This could include a brief overview of the subject area, recent developments in the field, key concepts, and existing knowledge gaps. The goal is to familiarize readers with the context of the study and establish its relevance.[3]

For example, if the research paper focuses on the development of a novel drug delivery system, discuss the current challenges in drug delivery, existing approaches, and limitations. Highlight the importance of improving drug delivery methods for enhanced therapeutic outcomes and patient compliance.[4]

Next, articulate the rationale behind the research. Explain why the topic is worth investigating and identify the specific research questions or objectives. Discuss the potential impact of the research findings on the field, healthcare, or society as a whole.[5]

For instance, elaborate on the significance of developing a new drug delivery system, such as improving treatment efficacy, reducing side effects, or addressing unmet medical needs. Emphasize how the proposed research addresses critical gaps in current knowledge and contributes to advancements in the field.[6]

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Clearly state the research objectives or hypotheses that guide the study. These should be specific, measurable, and achievable goals that the research aims to accomplish. Outline the main questions or aims of the study that will be addressed through data collection and analysis. [7]

For example, if the research aims to develop and evaluate a sustained-release formulation for a specific drug, the objectives may include formulating the drug in a suitable delivery system, characterizing its release profile, and assessing its pharmacokinetic properties. [8]

Finally, provide an overview of the paper's structure to orient readers to the organization and flow of content. Briefly describe the sections that will be covered, such as literature review, methodology, results, discussion, and conclusion.

By outlining the structure, readers can anticipate the progression of the paper and locate relevant information easily. This enhances readability and comprehension of the research findings. [9]

In summary, the introduction serves as a roadmap for the research paper, establishing the context, rationale, objectives, and structure of the study. It prepares readers for the upcoming sections and emphasizes the significance of the research topic. [10]

II. MATERIALS AND METHOD

PREFORMULATION STUDIES

Pre-formulation testing involves examining the physical and chemical characteristics of a pharmacological material both on its own and when mixed with other substances called excipients.Pre-formulation studies provide essential information for the development of an appropriate formulation for toxicological purposes. It provides the necessary information to determine the characteristics of the drug material and create a specific dose form. Therefore, the subsequent pre-formulation investigations were conducted for the acquired medication sample.[11]

STANDARD GRAPH OF NIFEDIPINE

Standard Stock solution:

A solution was prepared by dissolving 20 mg of Nifedipine in 100 ml of 0.1N HCL (1000 µg/ml).Calibration curve for Nifedipine in a solution of 0.1N hydrochloric acid (HCL). From the given stock solution, 1 ml was put into a 10 ml volumetric flask and the volume was adjusted to 10 ml, resulting in a concentration of 100 µg/ml of Nifedipine in the solution. Various portions of the solution, measuring 1.6, 1.8, 2, 2.2, and 2.4 ml, were transferred to a 10ml volumetric flask. The volume was then adjusted using 0.1N HCL, resulting in final standard concentrations of 16, 18, 20, 22, and 24 µg/ml. A standard curve was generated by measuring the absorbance of secondary stock solutions using a UV double beam spectrophotometer at a wavelength of 216 nm.[12]

Drug-Excipients Compatiblity study:

Nifedipine was mixed with all excipients, used in the formulation in different ratios and subjected to Physical observation/FTIR.

Drug-Excipient Compatiblity study (FTIR):

The IR absorption spectra of the pure medication and various excipients were obtained using the KBr disc method, within the range of 4000-400 cm-1. For each sample, 1-2 mg of the material being analysed was mixed with a specific amount (300-400 mg) of finely powdered and dried potassium bromide.Typically, these amounts are enough to produce a circular object with a diameter of 10-15mm and a compacted material of appropriate strength using a hydraulic press.[13]

III. EXPERMENTAL METHODS

FORMULATION AND PREPARATION OF NIFEDIPINE FLOATING TABLETS:

The formulations underwent preparation via the direct compression method, employing various polymers. The procedure commenced with the individual sieving of Nifedipine and other components through a sieve of size 60. Subsequently, all ingredients were meticulously combined through trituration for a duration of up to 15 minutes, ensuring homogeneity of the powder mixture. To facilitate compression, Magnesium stearate was employed as a lubricant. Tablet production ensued through direct compression, adhering to the specifications outlined in the formulation table. This methodical approach aimed to ensure uniformity and efficacy in the formulation of the tablets.

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Composition of different formulations[14]

Ingredients (mg)	**FI**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
Nifedipine	30	30	30	30	30	30	30
Carbapol	150	—	—	75	75	—	75
HPMC k100 M	—	150	—	75	—	100	50
Xanthan gum	—	—	150	—	75	50	25
Sodium Bi carbonate	70	70	70	70	70	70	70
Citric acid	50	50	50	50	50	50	50
PVP K30	50	50	50	50	50	50	50
Magnesium stearate	200	200	200	200	200	200	200
Talc	200	200	200	200	200	200	200
Total weight	750mg	750mg	750mg	750mg	750mg	750mg	750mg

EVALUATION OF PRE COMPRESSION PARAMETERS

Bulk density

The bulk density of a compound significantly differs depending on the procedure used for crystallisation, grinding, or formulation. Bulk density is calculated by pouring granules that have been pre-sieved into a graduated cylinder using a big funnel, and then measuring the volume and weight.

Tapped density:

The compound's bulk density varies greatly based on the specific techniques employed for crystallisation, grinding, or formulation. The calculation of bulk density involves the process of pouring pre-sieved granules into a graduated cylinder using a large funnel, followed by the measurement of both the volume and weight.

Carr's Index (CI)

For the purpose of calculating Carr's index, the values of bulk density and tapped density are utilised. In order to determine the Carr's index, the following equation is utilised.Table 6.3: Flow properties and corresponding Carr's Index values

Hausner's Ratio: It indicates the flow properties of the powder and ratio of Tapped density to the Bulk density of the powder or granules.

Hausner's Ratio = Tapped density / Bulk density

Angle of repose:

In order to determine Carr's index, the values of bulk density and tapped density are employed. This is done for the aim of computing the index. [15]

EVALUATION OF TABLETS:

The formulated tablets were evaluated for the following physicochemical characteristics:

General appearance:

The formulated tablets were assessed for its general appearance and observations were made for shape, color, texture and odor. [16]

Hardness:

The Monsanto hardness tester was utilised in order to ascertain the tablet's level of hardness. The bottom plunger was brought into contact with the tablet, and a reading of zero was obtained from the device. Following this, a threaded bolt was turned in order to drive the plunger against a spring until the tablet broke. The amount of force that was applied to the spring was indicated by a pointer that moved along a gauge that was located in the barrel.[17]

Weight Variation

A total of 20 pills were chosen and their weights were measured both collectively and individually. The average weight was determined by calculating the collective weight. Subsequently, the weight of each tablet was compared to the average weight in order to determine if it fell within the acceptable range. At most, two of the individual weights

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differed from the average weight of the 300 mg tablets by more than 7.5%, and none differed by more than twice that proportion.[17]

Friability test:

20 previously weighed tablets were placed in the friability apparatus, which was given 100 revolutions and the tablets were reweighed. The percentage friability was calculated by usingthe following formula,

Percentage friability = initial weight-final weight /initial weight × 100.

Drug content:

A total of twenty pills were chosen and their weights were measured collectively as well as individually. The average weight was calculated by adding together the weights and then dividing the sum by the number of items. Subsequently, the weight of each tablet was compared to the average weight in order to determine whether it was within the permissible range. At most, two of the individual weights differed from the average weight of the 300 mg tablets by more than 7.5%, and none differed by more than twice that amount.[17]

In-vitro Buoyancy studies:

The in-vitro buoyancy was determined by floating lag time, and total floating time. The tablets were placed in a 100ml beaker containing 0.1N HCl. The time required for the tablet to rise to the surface and float was determined as floating lag time (FLT) and the duration of the time the tablet constantly floats on the dissolution medium was noted as the Total Floating Time respectively (TFT).[18]

Swelling Index Studies:

The swelling behavior of a dosage unit wasmeasured by studying its weight gain. The swelling index of tablets was determined by placing the tablets in thebasket of dissolution apparatus using dissolution mediumas 0.1N HCl at 37±0.5°C. After 1, 4 and 6h each dissolution basket containing tablet waswithdrawn, blotted with tissue paper to remove theexcess water and weighed on the analytical balance(Schimdzu, AX 120). The experiment was performedin triplicate for each time point. Swelling index wascalculated by using the following formula.[18]

In-Vitro Dissolution Studies of Tablets:

Dissolution parameters:

Apparatus -- USP-II, Paddle Method
Dissolution Medium -- 0.1 N HCl
RPM -- 50
Sampling intervals (hrs) -- 0.5,1,2,3,4,5,6,8 and 10
Temperature -- 37 + 0.5°C [18]

Dissolution Study:

900ml 0f 0.1 HCl was placed in the vessel and the USP apparatus –II (Paddle Method) was assembled. The medium was allowed to equilibrate to temp of 37 + 0.5°C. Tablet was placed in the vessel and the vessel was covered, the apparatus was operated for 10 hours at 50 rpm. At definite time intervals, 5 ml of the fluid was withdrawn; filtered and again 5ml of the fresh buffer was replaced. Suitable dilutions were done with the dissolution fluid and the samples were analyzedspectrophotometrically at 216 nm.[19]

IV. RESULTS AND DISCUSSION

STANDARD GRAPH OF Nifedipine

The standard calibration curve of Nifedipine was constructed to determine the relationship between its concentration and the corresponding absorbance values. As depicted in Table 7.1, a series of standard solutions with concentrations ranging from 16 µg/ml to 24 µg/ml were prepared, and their absorbance values were measured at a specific wavelength.

Table 1 : standard calibration curve of Nifedipine

Conc (ug/ml)	Absorbance
16	0.321
18	0.372

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20	0.420
22	0.362
24	0.512

The resulting data were utilized to generate a calibration curve, with concentration plotted against absorbance.

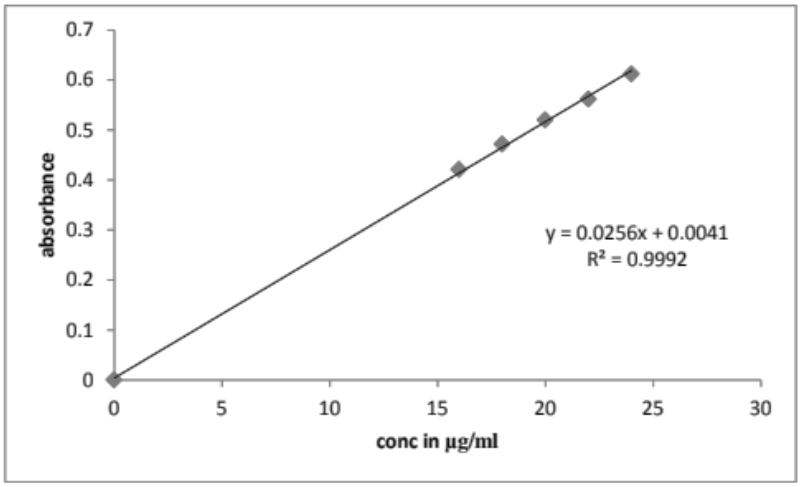

Fig 1: standaed calibration curve of Nifedipine

FT-IR STUDIES:

The FTIR spectra of the pure drug and the drug-polymer mixture were obtained using the potassium bromide pellet method to investigate potential interactions between the drug and the polymer.

IR SPECTROSCOPY

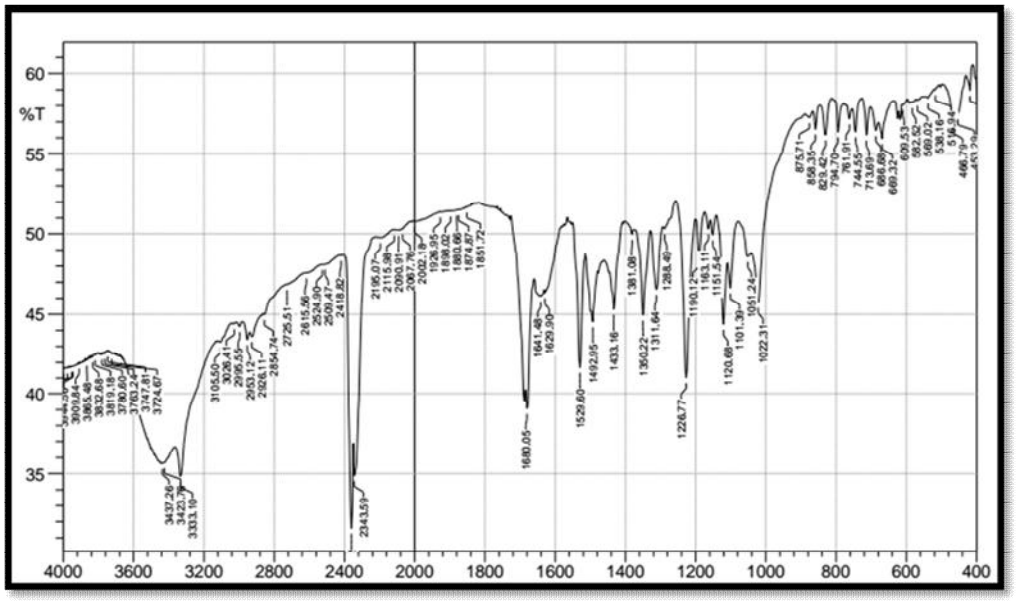

Fig 2: FTIR Spectra of Nifedipine

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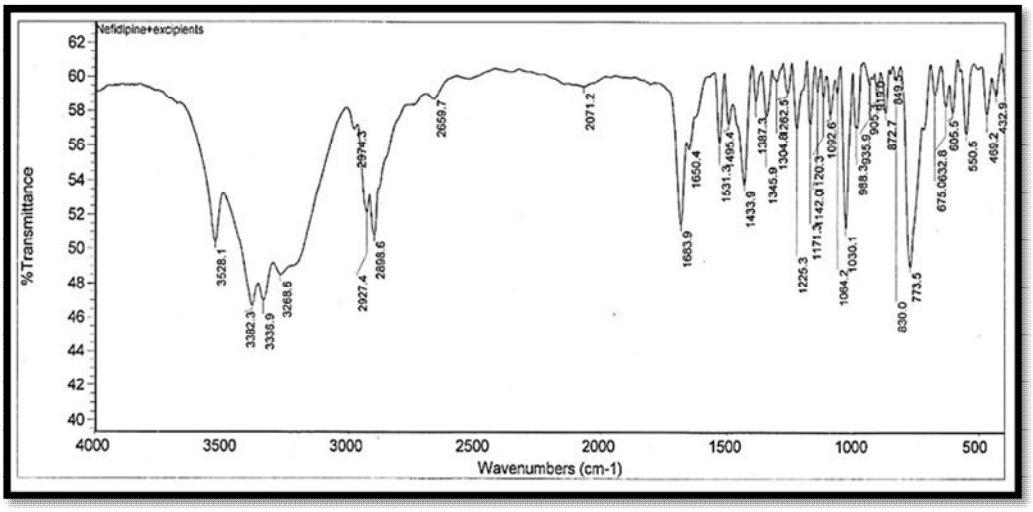

Fig 3: FTIR Spectra of Nifedipine final formulation

PREFORMULATION STUDIES OF POWDERED BLEND

Bulk density (gm/mL)

The pre-compression parameters for the powdered blend formulation batches were evaluated, with bulk density being a key parameter of interest. The bulk density reflects the mass of the blend per unit volume before compression and provides insights into the flow properties and packing characteristics of the powder.

Table 2:.Pre-compression parameters for formulation batches

Formulation code	Bulk density (gm / mL)
F1	0.67 ±0.035
F2	0.34±0.023
F3	0.41 ± 0.015
F4	0.52 ± 0.046
F5	0.75 ± 0.014
F6	0.56 ± 0.047
F7	0.54± 0.034
F8	0.62 ± 0.035
F9	0.48 ± 0.048

Tapped density (gm / mL)

The tapped density, another crucial parameter in pre-compression studies, provides insights into the packing arrangement and compaction behavior of powdered blends. Table 7.3 outlines the tapped density values obtained for each formulation batch.

Fig 3: Tapped density (gm / mL)

Formulation code	Tapped density (gm / mL)
F1	0.57± 0.01
F2	0.53 ± 0.04
F3	0.48 ± 0.5
F4	0.55 ± 0.09
F5	0.60 ±0.07
F6	0.50 ±0.09
F7	0.57± 0.01

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F8	0.45 ± 0.07
F9	0.53 ± 0.08

Compressibility index (%)

The compressibility index, expressed as a percentage, is a critical parameter in pre-compression studies that characterizes the ability of a powdered blend to be compressed into a tablet or compacted form.

Table 4: compressibility index

Formulation code	Compressibility index (%)
F1	16.236 ± 0.6
F2	14.224 ± 0.7
F3	17.313 ± 0.8
F4	16.10 ± 0.2
F5	11.23 ± 0.6
F6	13.18 ± 0.8
F7	15.313 ± 0.8
F8	16.123 ± 0.4
F9	13.112 ± 0.3

Hausner's ratio

Hausner's ratio is a parameter used to assess the flow properties of powdered blends and is calculated as the ratio of tapped density to bulk density.

Table 5: Hausner's ratio

Formulation code	Hausner's ratio
F1	1.146 ± 0.06
F2	1.211 ± 0.04
F3	1.48 ± 0.08
F4	1.45 ± 0.02
F5	1.51 ± 0.04
F6	1.33 ± 0.08
F7	1.38 ± 0.08
F8	1.61 ± 0.03
F9	1.31 ± 0.02

Angle of repose (θ)

The angle of repose (θ) is a key parameter used to assess the flow properties of powdered blends, representing the maximum angle formed between the surface of a pile of powder and the horizontal plane. Table 7.6 presents the angle of repose values obtained for each formulation batch.

Table 6 : angle of repose

Formulation code	Angle of repose (θ)
F1	23.62 ± 0.21
F2	28.64 ± 0.11
F3	29.34 ± 0.31
F4	31.46 ± 0.31
F5	25.28 ± 0.15
F6	27.24 ± 0.61
F7	32.46 ± 0.25
F8	33.23 ± 0.21
F9	34.47 ± 0.25

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The variations observed in the angle of repose among the formulations could be attributed to differences in particle size distribution, shape, and the presence of excipients. Additionally, the inter-particle interactions and powder characteristics, such as cohesiveness and adhesion, influence the flow behavior of the blend.

POST COMPRESSION PARAMETERS

Average Weight of tablet

The average weight of tablets, a critical post-compression parameter, provides insights into the uniformity and consistency of tablet manufacturing processes. Table 7.7 presents the average weight of tablets obtained for each formulation batch.

Table 6:presents the angle of repose

Formulation No.	Average Weight of tablet (Meant S.D) (n = 20)
F1	343 ± 0.6
F2	340 ± 0.9
F3	347 ±0.3
F4	341 ± 0.4
F5	336 ± 0.8
F6	334 ± 0.8
F7	367 ±0.3
F8	344 ± 0.2
F9	326 ± 0.8

Formulations F1 to F9 displayed average tablet weights ranging from 326 mg to 367 mg, with standard deviations indicating the degree of variation within each batch. Among the formulations, F7 exhibited the highest average tablet weight of 367 mg, while F9 demonstrated the lowest average tablet weight of 326 mg.

Hardness

Hardness, a key post-compression parameter, reflects the tablet's mechanical strength and resistance to breaking or crumbling under compression. Table 7.8 provides the hardness values obtained for each formulation batch.

Table 8:hardness values

Formulation No.	Hardness (kg/cm²) (n = 3)
F1	7.2 ± 0.4
F2	6.5 ± 0.4
F3	6.4 ± 0.6
F4	6.6 ± 0.1
F5	5.6 ± 0.6
F6	5.3 ± 0.4
F7	5.4 ± 0.6
F8	7.6 ± 0.1
F9	6.8 ± 0.2

Friability

Friability is a critical post-compression parameter that measures the tendency of tablets to undergo abrasion or breakage during handling and transportation. Table 7.9 presents the friability values obtained for each formulation batch.

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Table 9: friability

Formulation No.	Friability (Mean ± S.D)(n = 6)
F1	0.636±0.5
F2	0.532±0.2
F3	0.627±0.1
F4	0.541±0.4
F5	0.695±0.8
F6	0.585±0.2
F7	0.327±0.3
F8	0.422±0.3
F9	0.347±0.3

% Drug content (mg)

Based on the results obtained from the drug content analysis of the various formulations (F1-F9), it is evident that the formulations exhibit consistent drug content levels with minor variations.

Table 10: % Drug content (mg)

Formulation No.	% Drug content (mg)
F1	98.11 ± 0.7
F2	98.23± 0.5
F3	98 .43± 0.6
F4	99.44 ± 0.6
F5	98.22 ± 0.6
F6	98.52 ± 0.5
F7	98 .53± 0.6
F8	98.42 ± 0.3
F9	98.12 ± 0.1

The drug content ranged from 98.11 mg to 99.44 mg across the different formulations, with standard deviations ranging from 0.1 to 0.7 mg. Formulation F4 demonstrated the highest drug content (99.44 ± 0.6 mg), indicating the efficient incorporation of the active pharmaceutical ingredient. Conversely, formulation F1 exhibited the lowest drug content (98.11 ± 0.7 mg) among the formulations studied.

Buoyancy Lag time (min)

Table 11: Buoyancy Lag time (min)

Formulation No.	Buoyancy Lag time (min)
F1	24
F2	17
F3	22
F4	31
F5	58
F6	37
F7	24
F8	26
F9	21

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Total floating Time (hrs)

The investigation into the buoyancy lag time of the formulations (F1-F9) revealed notable variations in the time taken for the formulations to float. The buoyancy lag time ranged from 17 to 58 minutes across the different formulations. Formulation F5 exhibited the longest buoyancy lag time (58 minutes), indicating a delayed onset of buoyancy compared to other formulations. Conversely, formulations F2 and F9 demonstrated relatively shorter buoyancy lag times of 17 and 21 minutes, respectively.

Table 12 :Total floating Time (hrs)

Formulation No.	**Total floating Time (hrs)**
F1	4
F2	7
F3	11
F4	16
F5	8
F6	9
F7	12
F8	13
F9	11

These results suggest differences in the buoyancy properties of the formulations, which may be attributed to variations in the composition and physical characteristics of the dosage forms. Factors such as density, porosity, and surface morphology can influence the buoyancy behavior of the formulations. Formulations with shorter buoyancy lag times may offer quicker onset of gastric retention, potentially enhancing drug absorption and bioavailability.

Swelling index studies of floating Tablets

The swelling index studies of floating tablets provide valuable insights into the hydration and swelling behavior of the formulations over time. The swelling index ratio, expressed as a percentage, indicates the extent of swelling exhibited by the tablets at different time points.

Table 13: Swelling index studies of floating Tablets

Time (hr)	**Swelling index ratio (%)**								
	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**
0	0	0	0	0	0	0	0	0	0
2	31	33	44	42	52	53	51	43	38
4	48	42	55	54	8	65	63	54	51
6	54	55	56	64	68	73	75	67	78
8	49	50	57	56	58	63	64	59	62

As the study progressed, the swelling index ratios increased significantly for all formulations. By the end of 2 hours, formulations F5, F6, and F7 demonstrated notably higher swelling index ratios compared to others, indicating relatively faster hydration and swelling kinetics. Formulations F3, F4, and F6 also exhibited substantial swelling at this time point.

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Dissolution studies

The dissolution studies provide valuable insights into the drug release profiles of the floating tablets over time. The percentage of drug release (%DR) at different time points reveals the release kinetics and performance of the formulations.

Table 7.14: Dissolution profile of Floating Tablets

	% of Drug Release								
TIME(hr)	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**
1	17.8	15.3	13.3	12.5	13.4	9.5	9.2	10.1	11.7
2	38.9	25.2	24.4	28.8	34.8	18.3	12.3	21.5	19.3
3	51.3	33.6	35.8	43.9	44.3	25.7	33.6	41.3	33.5
4	75.9	43.8	47.1	54.2	46.4	35.2	47.1	48.2	41.9
5	91.8	73.8	57.4	66.1	66.3	47.8	57.4	52.8	55.5
6	92.8	92.3	68.5	76.7	76.4	59.3	76.7	61.2	66.8
8	92.8	94.3	78.9	93.3	97.2	70.4	93.3	79.6	74.8
10	92.8	95.3	91.4	96.4	98.4	87.9	96.4	85.8	89.3

As the dissolution study progressed, there was a significant increase in drug release for all formulations. By 2 hours, formulations F1, F2, and F5 demonstrated relatively higher drug release percentages compared to others. However, formulations F4, F6, and F7 exhibited slower drug release kinetics at this time point.

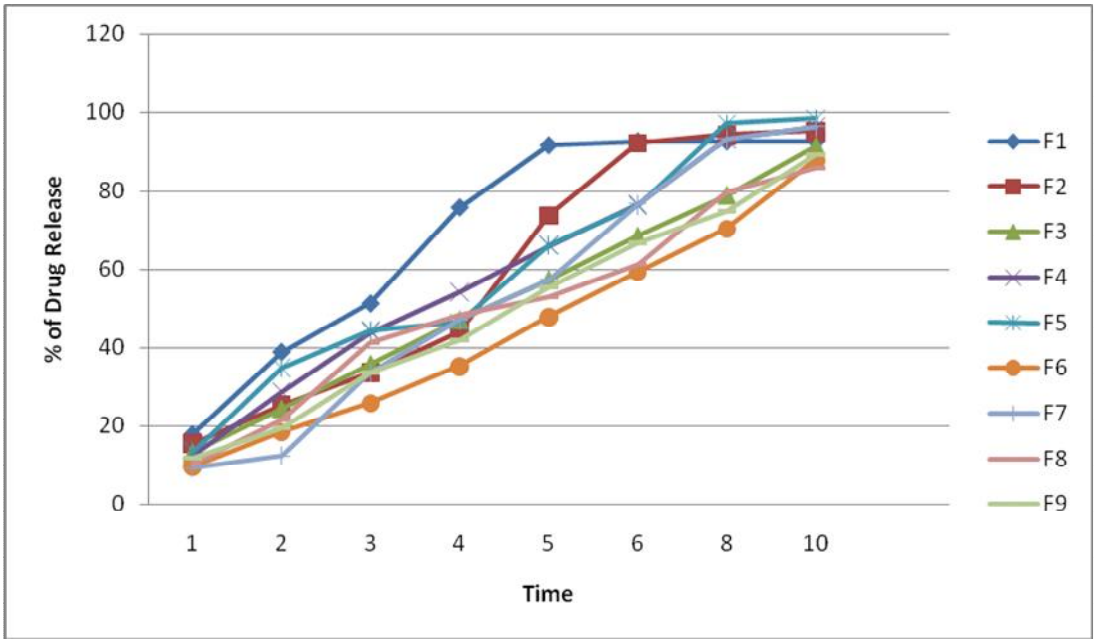

Fig 4: Dissolution profile of Floating Tablets

Overall, the dissolution studies reveal significant differences in the drug release profiles among the floating tablet formulations. Formulations F2, F4, F5, and F6 exhibited favorable dissolution characteristics, with sustained and efficient drug release over the studied time period. Further investigation into the formulation attributes and their correlation with dissolution behavior is warranted to optimize the performance of gastroretentive drug delivery systems.

KINETIC MODELLING AND MECHANISM OF DRUG RELEASE

The results of kinetic equations applied to dissolution profiles of optimized batch F5 were determined as follows.

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Table 14: Kinetic values obtained from different plots of F5 formulation

	ZERO ORDER	FIRST ORDER	HIGUCHI ORDER	PEPPAS ORDER
	% CDR Vs T	Log % Remain Vs T	% CDR Vs VT	Log C Vs Log T
Slope	10.0480	-0.1512	33.7231	1.4567
Intercept	7.4806	2.1695	-12.0120	0.7304
Correlation	0.9823	-0.9609	0.9772	0.8513
R2	0.9649	0.9235	0.9549	0.7247

The release kinetics of all the dosage forms were calculated using zero-order, first-order, higuchi and krosemeyer-peppas. Optimized formulation was found to follow higuchi release kinetics. The optimized formulation F5 was found to exhibit zero–order which shows that the diffusion along with dissolution of the drug from the tablet.

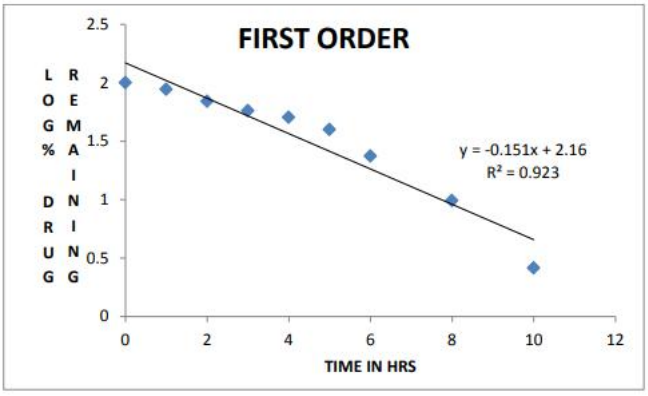

Fig 5: first order release model for F5 formulation

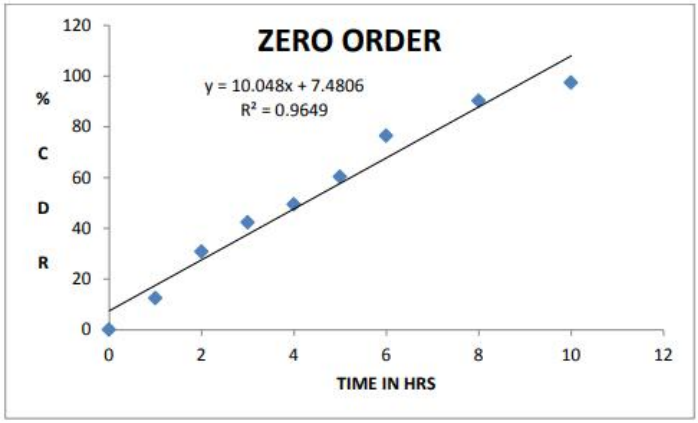

Fig6 : Zero order release model for F5 formulation

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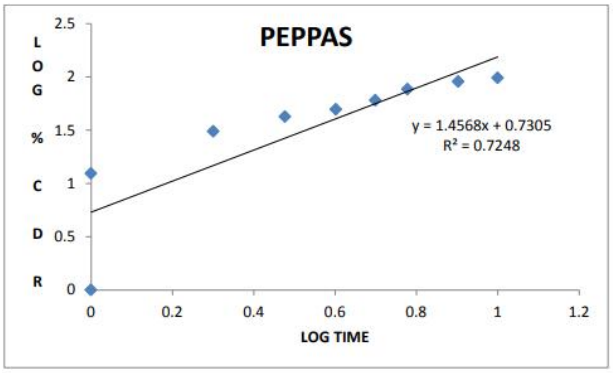

Fig 7: Peppas release model for F5 formulation

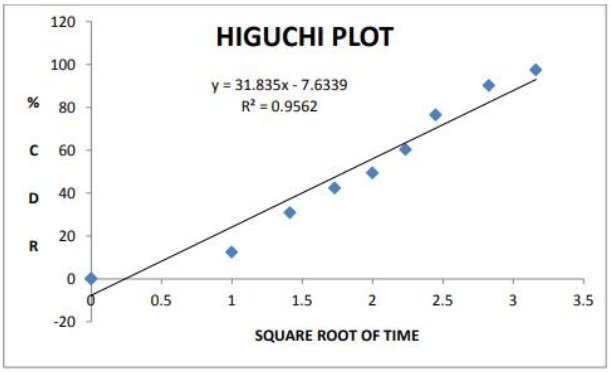

Fig 8: Higuchi release model for F5 formulation

Stability Study:

Stability studies were carried out on optimized formulation i.e. F5. The formulation was stored at 40 2°C/75 +5% RH for three months (90 days). After 90 days, samples were withdrawn and retested for thickness, hardness, drug content, and in-vitro drug release studies

Table 7.15: Stability Study

Parameters	0 day	At 1 month	At 2 month	At 3 month
Thickness(mm)	2.03	2.03	2.03	2.03
Hardness (kg / cm²)	6.0	6.0	6.0	6.1
Drug content %	101.92	101.87	101.89	101.90

V. CONCLUSION

In conclusion, this study comprehensively investigated the pre-formulation, formulation, and evaluation of floating tablets of Nifedipine. Pre-formulation studies provided crucial insights into the physical and chemical characteristics of the drug and its compatibility with excipients. Formulation of floating tablets was achieved using various polymers via the direct compression method. Evaluation of pre-compression and post-compression parameters revealed the uniformity and quality of the formulated tablets.

The study conducted dissolution studies to assess drug release profiles over time and employed kinetic modeling to understand the mechanism of drug release, which was found to follow Higuchi kinetics. Stability studies demonstrated the robustness of the optimized formulation over a three-month period.

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Overall, this research contributes to the development of gastroretentive drug delivery systems, offering potential benefits in terms of enhanced drug bioavailability and patient compliance. Further research and optimization efforts can build upon these findings to refine and optimize the formulation for clinical applications.

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