

## DESIGN AND EVALUATION OF CONTROLLED RELEASE TABLETS OF LIPID LOWERING AGENTS FOR HYPERLIPIDEMIA

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### ABSTRACT

Nicotinic acid (NA) although known since decades, as a lipid lowering agent drug has not become a first-line treatment due to the strong side effect called flushing occurs when given in Immediate release (IR) dosage form. In the present research, an attempt has been made to formulate controlled release matrix tablets of Nicotinic acid (NA). The tablets were prepared by wet granulation method and the prepared tablets of NA will remain intact up to 2 hrs even in pH 1.2 due to eudragit S100 and its release is not only initiated but tact fully retarded up to 12 hrs and were found to be superior in physical properties, dissolution characteristics, and drug content uniformity. The *in vitro* NA release data justified the release mechanism to be Case-II and anomalous transport was found to be a mixed pattern of zero order and Korsmeyer-Peppas release models. The accelerated stability studies of optimized formulation FA5 made it clear that the drug content degradation was very negligible. Release pattern was almost unaffected and could be claimed to be stable at the end of three months.

**Keywords:** Nicotinic acid (NA), HPMC K-4M, Eudragit S100, Controlled Release (CR)

### INTRODUCTION

Hyperlipidemia (HPL) is a major cause of atherosclerosis and atherosclerosis-associated conditions, such as coronary heart disease (CHD), ischemic cerebrovascular disease, and peripheral vascular disease. These conditions account for the majority of morbidity and mortality among middle-aged and older patients. HPL and low levels of high-density-lipoprotein cholesterol (HDL-C) are major causes of increased atherogenic risk; both genetic disorders and lifestyle contribute to the HPL seen in developed countries around the world<sup>1</sup>

NA has been used to treat HPL for more than 50 years. In pharmacologic doses, NA has multiple effects on lipoprotein metabolism. In adipose tissue, NA inhibits the lipolysis of triglycerides by hormone sensitive lipase. In the liver NA reduces triglyceride synthesis by inhibiting both the synthesis and esterification of fatty acids, effects that increase apoB degradation. NA also enhances LPL activity, which promotes the clearance of chylomicrons and VLDL triglycerides. NA raises HDL-C (good cholesterol) levels by decreasing the fractional clearance of apoA-lin HDL rather than by enhancing HDL synthesis<sup>1</sup>.

In clinical practice, however, the use of NA has been limited by poor tolerability, primarily due to cutaneous flushing. Flushing occurs in nearly all patients treated with immediate-release NA. CR formulations were developed to reduce flushing and improve tolerability.

IR dosage form of NA is required to administer three times per day after meals. While such a regimen does produce cutaneous flushing. A method of avoiding or reducing the side effects associated with immediate release of drugs like NA is the use of CR formulations. CR formulations are designed to slowly release the active ingredient from the tablet, which allows a reduction in dosing frequency as compared to the typical dosing frequency associated with conventional or immediate dosage forms. The controlled drug release reduces and prolongs blood levels of the drug, and thus minimizes or lessens the cutaneous flushing side effects that are associated with conventional or immediate release NA products.

The oral route of drug delivery is the most popular, desirable and preferred method of administering therapeutic agents for systemic effects because it is convenient for the patient, and cost effective to manufacturing process. Tablets are the most popular oral formulations available in the market and preferred by the patients and physicians alike<sup>2</sup>.

CR tablet formulations are much desirable and preferred for such therapy because they offer better patient compliance, maintain

uniform drug levels, reduce dose and side effects, and increase safety margin for high potency drugs<sup>4</sup>. The most commonly used method of modulating the drug release is to include it in a matrix system<sup>5</sup>.

**Aim of the work:** The aim of this present work is to formulate a controlled release matrix tablet of Nicotinic acid by wet granulation method using polymer such as HPMC K-4M. NA has a short biological half life of 1-2 hour and rapid first pass metabolism which necessitates multiple daily dosing hence the present study was aimed to develop a controlled release formulation of NA. The best formulation is to be selected on the basis of evaluation characteristics.

**The scope of the present work is:** To provide a drug delivery system for continuous release of drug at controlled rate and maintains the therapeutic blood plasma concentration for a required period of time.

### METHODOLOGY

#### Construction of standard curve for NA

##### A. Preparation of Standard Calibration Curve of NA in pH1.2

**Preparation of Stock Solution:** 100mg of NA was dissolved in 100ml of pH 1.2 buffers so as to get a stock solution of 1000 µg/ml concentration

**Preparation Standard Solution:** 1ml of stock solution was diluted to 100ml with pH 1.2 buffer in 100ml volumetric flask this gives a concentration of 10 µg/ml. Aliquot of standard drug solutions were prepared by withdrawing 2, 4, 6, 8, 10ml and transferred in to 10ml volumetric flask and were diluted up to the mark with pH 1.2 buffer. This gives the final concentration of 2, 4, 6, 8, 10µg/ml of NA respectively. The absorbances of the solution were measured against pH 1.2 as blank at 260.5nm using UV visible spectrophotometer. The absorbance values were plotted against concentration (µg/ml) to obtain the standard calibration curve.

##### B. Preparation of Standard Calibration Curve of NA in pH6.8

**Preparation Stock Solution:** 100mg of NA was dissolved in 100ml of pH 6.8 buffers so as to get a stock solution of 1000 µg/ml concentration

**Preparation Standard Solution:** 5ml of stock solution was diluted to 100ml with phosphate buffer pH 6.8 this gives a concentration of 50 µg/ml. Aliquot of standard drug solution ranging from 1ml to 7ml were transferred in to 10ml volumetric flask and were diluted up to the mark with pH 6.8 phosphate buffer. Thus the final concentration ranges from 5-35 µg/ml. Absorbance of each

solution was measured at 262.4nm against phosphate buffer pH 6.8 as a blank. A plot of concentrations of drug vs. absorbance was plotted.

#### Preparation of NA Matrix Tablets

Controlled release tablets of NA were prepared by wet granulation technique using variable concentrations of different polymers like HPMC K4M, Eudragit S100, guar gum, and Polyvinylpyrrolidone-K-30. Different steps in Wet Granulation.

**a) Weighing and blending:** Specified quantity of all materials was weighed and then active ingredient (NA) and polymers were mixed by mortar pestle. Then solution of Eudragit S100 (previously dissolved in isopropyl alcohol by continuous stirring) is added to the above mix.

**b) Preparation of dump mass:** A liquid binder solution of PVP K30 is added to the mixture to facilitate adhesion. A damp mass resembling dough is formed and used to prepare the granulation.

**c) Screening the dump mass into pellets or granules:** The wet mass was pressed through a 10 number sieve to prepare the

granules. This is done by hand. The resultant granules are spread evenly on large pieces of paper in shallow trays and dried

**d) Drying the granulation:** Granules were dried in hot air oven (Servewell Instrument PVT LTD, Bangalore.) at 60°C for 1 to 2 hrs

**e) Sizing the granulation by dry screening:** Here granules were passed through sieve number 20. Sizing of the granules is necessary so that the die cavity for tablet compression may be completely and rapidly filled by the free flowing granulation.

**f) Adding lubricant and blending:** After completion of dry screening the granules were mixed with magnesium stearate and talc which acts as lubricants which prevents the adhesion of the tablet formulation to the punches and dies during compression.

**Forming tablets by compression:** After blending with the polymers the granules were subjected to the compression using 10 stations tablet punching machine (Rimek mini press-1 Karnavati Engineering Ltd, Mehsana, Gujarat.)

**Table 1: Tablet composition of different formulations of NA matrix tablets containing HPMC K4M as controlled release polymer**

Ingredients (mg)	Formulation Code					
	F1	F2	F3	F4	F5	F6
Nicotinic acid	500	500	500	500	500	500
Eudragit S100	60	75	90	90	90	90
HPMC K4M	100	100	100	135	170	205
PVP K30	46	46	46	46	46	46
Micro. cellulose	40	40	40	40	40	40
Lactose	31	31	31	31	31	31
Mg stearate	14	14	14	14	14	14
Talc	9	9	9	9	9	9

#### Evaluation Parameters<sup>6,7</sup>

**Pre and post Compression Parameters:** Parameters like bulk density (BD), tapped density (TD), Carr's index (CI), Hausner's ratio, angle of repose were evaluated before compression. And the parameters like weight variation, hardness (Monsanto Hardness Tester), thickness (Digital Vernier Caliper, Mitutoyo, Chaina), friability (using Friabilator USP EF-2), were evaluated after compression of the tablet.

**Uniformity of drug content:** Five tablets of various formulations were weighed individually and powdered. The powder equivalent to average weight of tablets was weighed and drug was extracted in Phosphate buffer pH 6.8, the drug content was determined measuring the absorbance at 262.4 nm after suitable dilution using a UV/Visible Spectrophotometer (UV-1800).

#### In-vitro release study:

Apparatus	USP XXIV dissolution testing apparatus II (paddle method)
Dissolution medium	Phosphate buffer pH- 6.8
Temperature	37 ± 0.5 °C
RPM	50
Vol. withdrawn and replaced	5ml every 1 hour
λ max	260.5 in pH 1.2 and 262.4 nm in pH 6.8
Blank solution	Phosphate buffer pH- 6.8
Duration of study	12 hours
Volume of dissolution media	900ml

**Procedure:** The release rate of NA from tablets was determined using The United States Pharmacopoeia (USP) XXIV dissolution testing apparatus II (paddle type). The dissolution test was performed using 900 ml of pH 1.2, for first 2 hours then in phosphate buffer pH 6.8 for rest of the hours at 37 ± 0.5°C and 50 rpm. A sample (5 ml) of the solution was withdrawn from the dissolution apparatus hourly for 12 hours, and the samples were replaced with fresh dissolution medium. The samples diluted to a

suitable concentration with respected dissolution medium. Absorbance of these solutions was measured using a UV-Visible Spectrophotometer (UV-1800). Cumulative percentage of drug release was calculated.

**Drug-polymer compatibility studies:** Studies were carried out using FTIR spectrophotometer (FTIR 1700S Spectrophotometer Shimadzu, Japan) by KBr pellet method, pellets were prepared at 15kg/cm<sup>2</sup> using Hydraulic pellet press, Mumbai, India.

**Stability Studies:** Stability studies of pharmaceutical products were done as per ICH guide lines. These studies are designed to increase the rate of chemical or physical degradation of the drug substance or product by using exaggerated storage conditions.

**Method:** Selected formulations were stored at different storage conditions at elevated temperatures such as 25°C ± 2°C / 60% ± 5% RH, 30°C ± 2°C / 65% ± 5% RH and 40°C ± 2° / 75% ± 5% RH for 90 days. The samples were withdrawn at intervals of fifteen days and checked for physical changes, hardness, friability, drug content and percentage drug release.

#### RESULTS AND DISCUSSION

**Compatibility studies:** Study is carried out using FTIR spectrophotometer (FTIR 1700S Spectrophotometer Shimadzu, Japan) by KBr pellet method, the spectra of drug with excipients and polymers confirms that drug is compatible with all excipients (fig 3-fig 7).

**Pre and Post compression parameters:** Granules prepared by wet granulation method were evaluated for pre compression parameters measurement of bulk density and angle of repose, Hausner's ratio, compressibility index and drug content. The results of angle of repose (<30) indicate good flow properties and the values for prepared formulations ranges from 24.22-29.74. generally Hausner's ratio less than 1.25 shows good flow property and values for all formulation were between the range of 1.17-1.23. Compressibility index values up to 15% result in good to excellent

flow properties and values for all formulation ranges from 9.54%-13.46%. All these results obtained indicate that the granules possessed satisfactory flow properties, compressibility, (Result shown in Table 5). Drug content for all the formulations were in the ranges from 97.56-100.04% (table 7). The tablet formulations were subject to various post evaluation tests (table 6) such as thickness, diameter, uniformity of weight, drug content, hardness, friability. All the parameters pass the pharmacopoeial limits.

Dissolution study: Dissolution study is carried out using USP-2 apparatus result shown in the table 8, the release of the formulation

F5 shows the release up to 12hrs. And it can be drawn that release rate decreases as the concentration of the polymer increases. Correlation coefficients of different mathematical models for formulations F-1 to F-6 was calculated (table 9), and graphs of optimized formula F5 were plotted.

**Stability studies:** Stability studies were carried as per ICH guidelines for the period of 90 days, samples are checked periodically, the results in the table 10 to table 13, confirms that the prepared tablets were stable with respect to appearance, physical parameters, dissolution study.

Table 2: Standard Calibration Curve of NA in pH1.2

Sr. No.	Concentration ( $\mu\text{g/ml}$ )	Absorbance In pH 1.2
1.	2	0.096
2.	4	0.192
3.	6	0.292
4.	8	0.389
5.	10	0.485

$$Y = 0.048; R^2 = 1$$

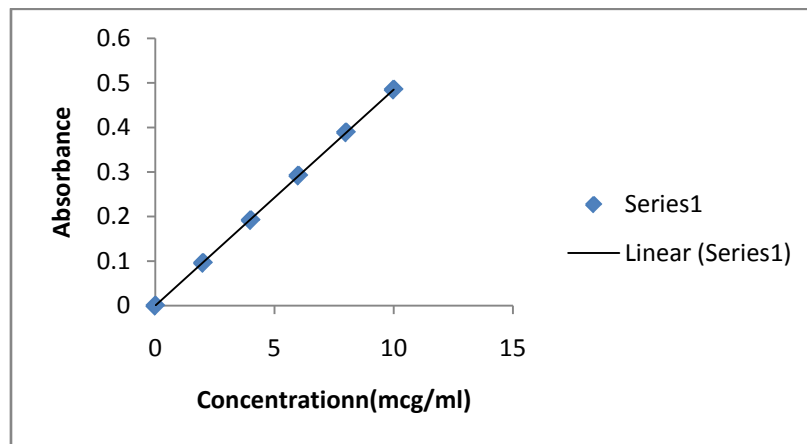


Fig. 1: standard calibration curve of NA in pH1.2

Table 3: Standard Calibration Curve of NA in pH6.8

Sr. No.	Concentration ( $\mu\text{g/ml}$ )	Absorbance In Phosphate buffer (pH6.8)
1.	5	0.148
2.	10	0.301
3.	15	0.431
4.	20	0.519
5.	25	0.671
6.	30	0.761
7.	35	0.902

$$Y = 0.026; r^2 = 0.993$$

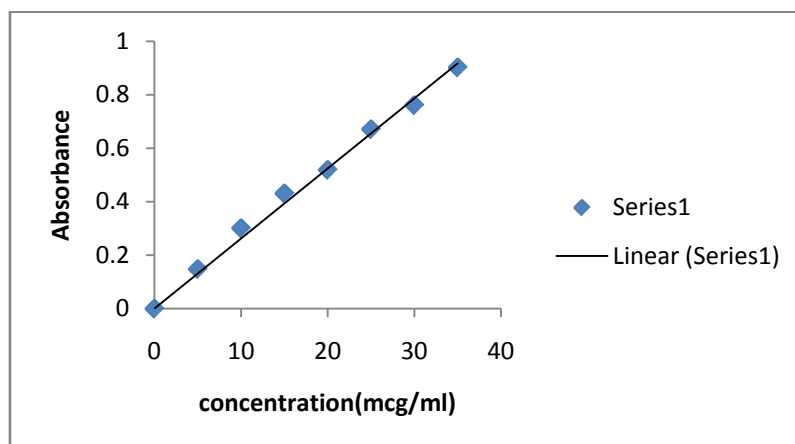


Fig. 2: standard calibration curve NA in pH6.8

FTIR studies

Spectrum of pure NA

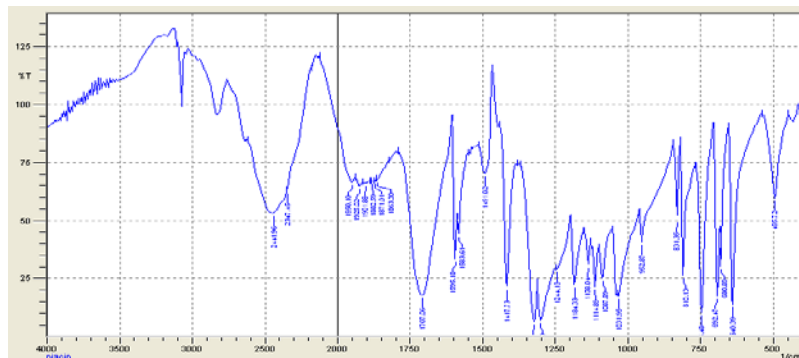


Fig. 3: FTIR spectrum of pure NA

Spectrum of pure HPMC K4M

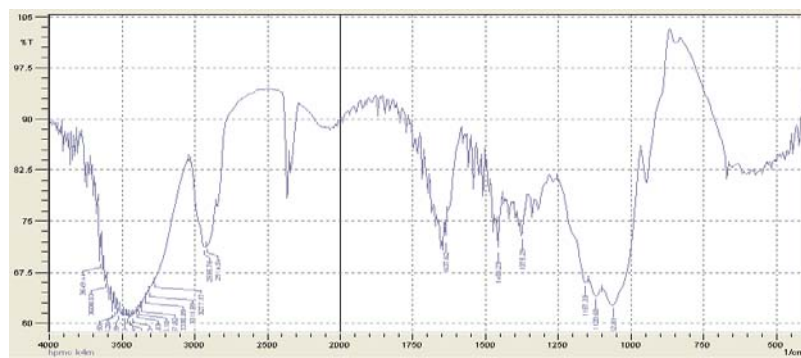


Fig. 4: FTIR spectrum of pure HPMC K4M

Spectrum of pure Eudragit S100

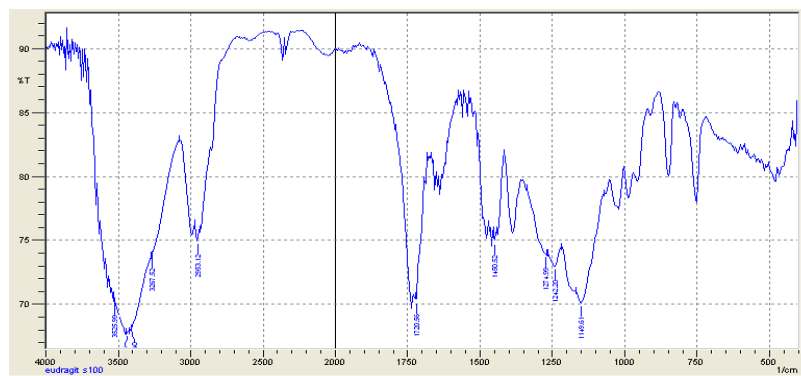


Fig. 5: FTIR spectrum of pure Eudragit S100

Spectrum of mixture of Eudragit S100, NA and HPMC K4M

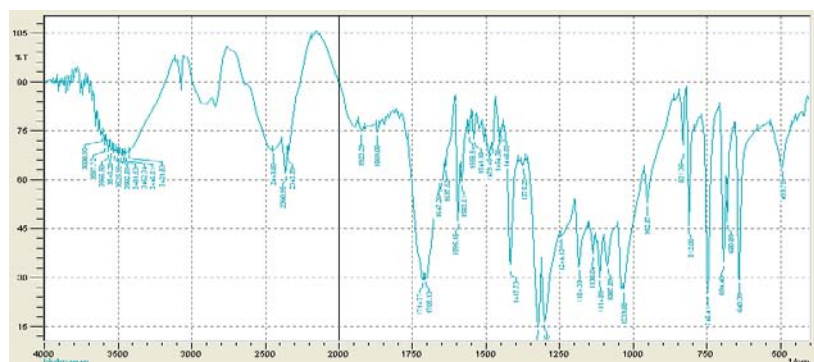


Fig. 7: Spectrum of mixture of Eudragit S100, NA and HPMC K4M

## Evaluation of NA Tablets

Table 5: Pre Compression Parameters

Parameters	Formulation Code					
	F1	F2	F3	F4	F5	F6
Angle of repose	24.22 ± 1.25	25.15 ± 1.31	27.22 ± 1.59	28.39 ± 1.52	29.74 ± 1.67	28.56 ± 0.492
Loose bulk density (LBD) (g/ml)	0.238 ± 0.008	0.242 ± 0.009	0.028 ± 0.009	0.236 ± 0.007	0.237 ± 0.006	0.2150 ± 0.005
Tapped bulk density (TBD) (g/ml)	0.263 ± 0.010	0.277 ± 0.018	0.259 ± 0.014	0.267 ± 0.012	0.265 ± 0.011	0.2484 ± 0.018
Compressibility index (%)	9.54 ± 0.71	12.63 ± 1.78	11.71 ± 1.56	11.20 ± 1.23	10.56 ± 0.78	13.46 ± 0.45
Hausner's ratio	1.21 ± 0.01	1.19 ± 0.01	1.23 ± 0.02	1.22 ± 0.01	1.17 ± 0.02	1.18 ± 0.01

Table 6: Post Compression Parameters

Parameters	Formulation code					
	F1	F2	F3	F4	F5	F6
Thickness (mm)	7.0 ± 0.011	7.05 ± 0.012	7.08 ± 0.008	7.12 ± 0.013	7.21 ± 0.019	7.31 ± 0.016
Hardness (kg/cm <sup>2</sup> )	7 ± 0.10	6.6 ± 0.52	7.1 ± 0.12	6.5 ± 0.00	6.8 ± 0.35	6.6 ± 0.10
Friability (%)	0.062 ± 0.029	0.081 ± 0	0.02 ± 0.028	0.076 ± 0.054	0.055 ± 0.026	0.089 ± 0.025

Table 7: Drug Content Uniformity

Tablet formulation	Calculated value (mg)	Estimated value (mg)	% Of drug content
F1	500	487.8	97.56
F2	500	492.6	98.52
F3	500	492.2	98.45
F4	500	495.5	99.11
F5	500	499.45	99.89
F6	500	500.2	100.04

Table 8: Percentage drug release of formulations F1-F6

Sr. No.	Time (hrs)	Formulation Code					
		F1	F2	F3	F4	F5	F6
<b>In acidic buffer pH 1.2</b>							
1	0	0.0	0.0	0.0	0.0	0.0	0.0
2	1	11.1	9.02	7.11	7.89	7.78	7.49
3	2	17.37	14.11	9.8	10.65	9.89	10.1
<b>In phosphate buffer pH 6.8</b>							
4	3	23.75	21.47	20.86	21.33	23.56	17.11
5	4	28.58	30.03	25.11	24.89	28.31	22.13
6	5	38.73	36.33	31.03	31.63	31.88	28.34
7	6	50.01	41.09	38.15	40.14	35.04	34.78
8	7	60.23	56.32	47.01	49.23	40.05	40.94
9	8	73.5	69.95	60.08	61.73	46.89	46.15
10	9	85.95	80.05	71.12	72.01	52.05	52.47
11	10	97.3	94.3	88.03	82.12	65.03	57.23
12	11	94.11	86.13	81	97.74	77	66.05
13	12	86.66	75	72.04	91	97.23	79.88

## Drug release profiles

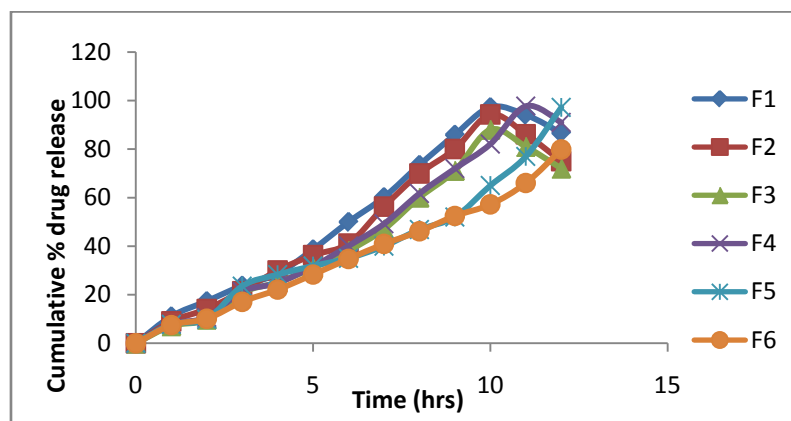
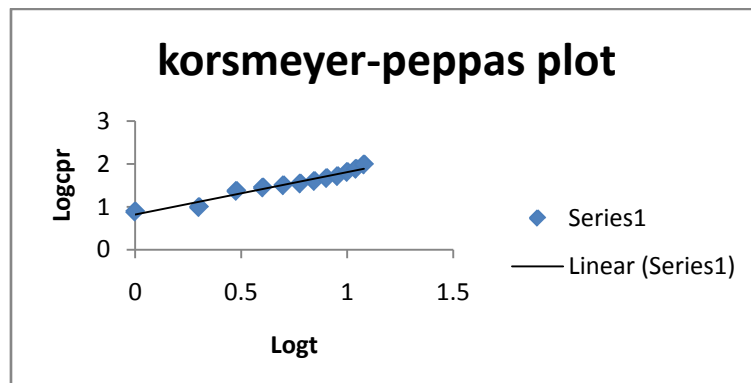
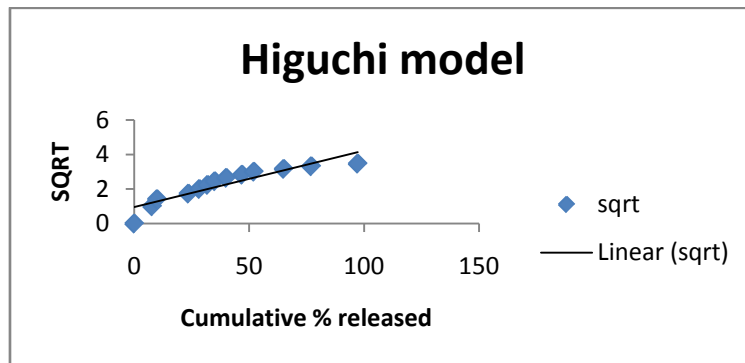
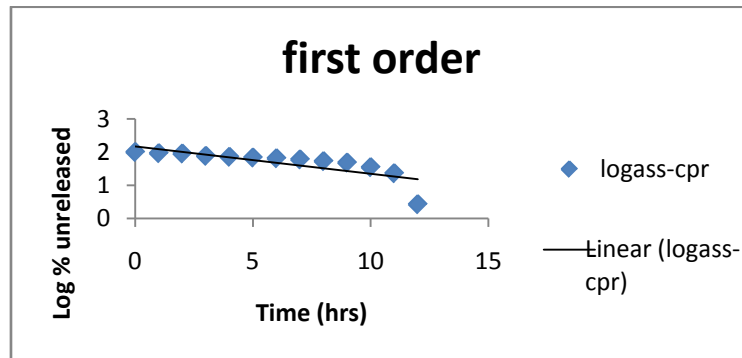
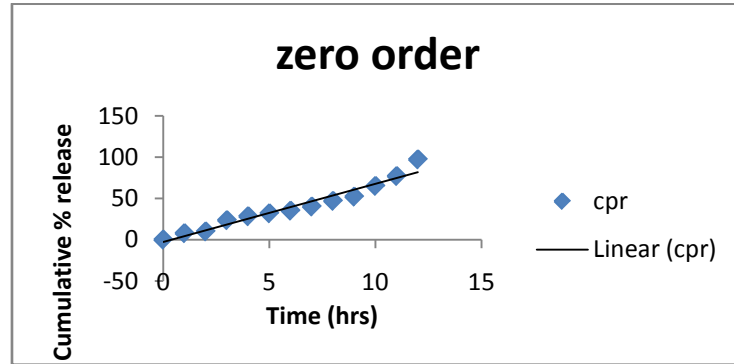


Fig. 8: In-vitro dissolution profile of F1 to F6 formulations

Table 9: Correlation coefficients of different mathematical models for formulations F-1 to F-6

Formulations	Zero order	R <sup>2</sup>	First order	R <sup>2</sup>	Higuchi's R <sup>2</sup>	Korsmeyer-peppas	
						R <sup>2</sup>	n value
F1	0.959		0.582		0.888	0.972	0.949
F2	0.932		0.714		0.869	0.972	0.995
F3	0.944		0.798		0.860	0.971	0.967
F4	0.978		0.683		0.862	0.976	0.981
F5	0.948		0.598		0.833	0.959	0.986
F6	0.988		0.890		0.886	0.983	0.978

## Model fitting for formulation F-5



## Stability studies

Table 10: Physical appearance of optimized formulation after stability studies

Temp. and relative humidity	Days				Parameters
	0	30	60	90	
25°C± 2°C / 60% ± 5% RH	No change				Physical appearance
30°C± 2°C / 65% ± 5% RH					
40°C± 2°C / 75% ± 5% RH					

Table 11: physical parameters of optimized formulation after stability studies

No. of days	Physical parameters								
	Hardness (Kg/cm <sup>2</sup> )			Friability (%)			Drug content (%)		
	25±2°C 60±5% RH	30±2°C65± 5%RH	40±2°C75± 5%RH	25±2°C 60±5% RH	30±2°C65± 5%RH	40±2°C75± 5%RH	25±2°C 60±5% RH	30±2°C65± 5%RH	40±2°C75± 5%RH
Initial	6.5 ± 0.35	6.7 ± 0.21	6.8 ± 0.32	0.11	0.14	0.11	99.30	99	99.30
30	6.5 ± 0.35	6.8 ± 0.25	6.8 ± 0.3	0.07	0.11	0.074	99.30	98.88	99.45
60	6.6 ± 0.31	6.8 ± 0.28	6.9 ± 0.35	0.14	0.11	0.037	99.11	99.05	99.08
90	6.7 ± 0.38	6.9 ± 0.3	7.1 ± 0.35	0.074	0.074	0.037	99.18	98.91	99.21

Table 12: Dissolution study for optimized formulation after stability studies

Time In hours	Cumulative percentage drug release								
	After 1 month			After 2 month			After 3 month		
	25±2°C 60±5% RH	30±2°C65± 5%RH	40±2°C75± 5%RH	25±2°C 60±5% RH	30±2°C65± 5%RH	40±2°C75± 5%RH	25±2°C 60±5% RH	30±2°C65± 5%RH	40±2°C75± 5%RH
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	7.23	7.58	7.78	7.91	7.68	7.77	7.89	7.81	7.1
3	10.88	10.23	9.89	10.89	10.56	11	11.11	10.51	11.23
4	21.83	22.11	22.56	23.56	21.46	22.56	21.73	23.81	22.57
5	25.09	26.41	27.18	28.31	27.66	28.01	25.33	27.56	27.11
6	30.89	32.18	31.28	31.33	31.88	31.88	29.81	31.81	31.08
7	35.48	35.19	35.53	35.04	35.81	35.04	34.55	36.45	35.85
8	41.11	40.52	41.09	42.51	41.43	41.23	41.03	42.03	41.67
9	47.71	46.89	47.01	51.01	47.32	46.31	47.03	50.07	47.88
10	56.62	55.78	54.09	58.33	53.01	54.08	56.08	58.11	52.03
11	65.81	63.78	64.01	68.7	65.33	69.31	67.11	66.15	63.76
12	78.14	74.77	77.01	79.11	76.66	79.27	83.01	77.09	75.23
13	98.03	97.11	97.85	95.68	97.11	96.89	97.33	96.23	95.87

Table 13: Correlation coefficients of different mathematical models for optimised formulation after stability studies

Mathematical models	After 1 month			After 2 month			After 3 month		
	25±2°C 60±5% RH	30±2°C65± 5%RH	40±2°C75± 5%RH	25±2°C 60±5% RH	30±2°C65± 5%RH	40±2°C75± 5%RH	25±2°C 60±5% RH	30±2°C65± 5%RH	40±2°C75± 5%RH
Zero order R <sup>2</sup>	0.960	0.956	0.953	0.971	0.956	0.956	0.957	0.968	0.957
First order R <sup>2</sup>	0.554	0.563	0.556	0.677	0.578	0.611	0.609	0.637	0.622
Higuchi's R <sup>2</sup>	0.838	0.841	0.835	0.857	0.840	0.838	0.829	0.857	0.845
Korsmeyer-peppas R <sup>2</sup>	0.978	0.971	0.965	0.973	0.973	0.970	0.970	0.972	0.978
Korsmeyer-peppas n value	0.993	0.998	0.996	0.992	0.993	0.988	0.997	0.993	0.994

## CONCLUSION

In this study matrix tablet of NA were prepared by wet granulation technique, using HPMC K-4M, polymer as retardant. The drug-polymer ratio was found to influence the release of drug from the formulations. It was found that increase in the concentration of HPMC K-4M in polymeric ratio decreases the drug release. The formulations F-4, and F-5 showed good drug release with good matrix integrity but the formulation F-4 showed the release up to 11hr (i.e.97.74% release at the end of 11hr) while the formulation F-5 showed the release of 97.23% at the end of 12hr so the formulation F-5 selected as the optimized formula . The enteric coated polymer Eudragit S100 was used to avoid the drug release in

stomach because the drug is quiet unstable in stomach and the aim of the work is to release the drug in intestine.

The formulation F-5 showed good drug release with good matrix integrity. Different parameters like hardness, friability, weight variation, drug content uniformity, *in-vitro* drug release were evaluated. Based on these results formulation F-5 was found to be the most promising formulations. The regression coefficient (R<sup>2</sup>) of Higuchi plot of optimized formula F-5 shows that the drug releases through the matrix was diffusion and slope (n) value of peppas plot confirms that non-Fickian diffusion (anomalous transport) was the main mechanism. The regression coefficient (R<sup>2</sup>) values of zero order of the optimized formulation F-5 was greater than the R<sup>2</sup>

values of first order. Thus, the drug release follows zero order release kinetics.

Stability studies were conducted for the optimized formulations as per ICH guidelines for a period of 90 days which revealed the stability of the formulations. The results suggest that the developed controlled-release matrix tablets of NA could perform better than conventional dosage forms, leading to improve efficacy and better patient compliance. Thus the aim of this study was achieved. Further preclinical and clinical studies are required to evaluate the efficacy of these formulations of NA in the management of Hyperlipidemia.

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