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Original Article

Design and Formulation of Once Daily Naproxen Sustained Release Tablet Matrix from Methocel K 15M CR and Methocel K 100M CR

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Abstract

The purpose of this work was to develop once daily sustained release (SR) matrix tablets of naproxen, an anti-inflammatory agent. The tablets were prepared by wet granulation method along with hydrophilic matrix materials like Methocel K 15M CR and Methocel K 100M CR. The granules were evaluated for bulk density, angle of repose, compressibility index, total porosity and drug content. The tablets subjected to thickness, diameter, weight variation test, drug content, hardness, friability, and *in vitro* release studies in buffer medium (pH, 7.4). The granules prepared either by Methocel K 15M CR or Methocel K 100M CR did not show satisfactory flow properties and compressibility, and had difficulty in sieving and individual in drug release. On the other hand, tablet matrix prepared along with Methocel K 15M CR and Mehtocel K 100 LV CR polymers of the proposed formulation F-8 showed desired drug release up to 24 h. All the formulations followed first order release kinetics (except F-2 and F-4), exhibited diffusion dominated drug release when data plotted into Korsmeyer Peppas equation. The matrix tablet of naproxen using hydroxypropyl methylcellulose derivatives controls the drug release effectively for 24 h; hence, the formulation can be considered as once daily sustained release tablet of naproxen in order to improve patient compliance.

Keywords: Direct compression; Methocel K15M CR; Methocel K100M CR; Naproxen; Sustained release.
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1. Introduction

Naproxen is a non-steroidal anti-inflammatory drug (NSAID) commonly used for the reduction of mild to moderate pain, fever, inflammation and stiffness caused by conditions such as osteoarthritis, rheumatoid arthritis, psoriatic arthritis, gout, ankylosing spondylitis, injury, menstrual cramps, tenditis, bursitis and the treatment of primary dysmenorrhea [1]. It works by reducing hormones that cause inflammation and pain in the body. With many drugs, the basic goal of

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therapy is to achieve a steady state blood or tissue level which will be therapeutically effective and non-toxic for extended periods of time [2]. A basic objective in dosage form design is to optimize delivery of medication so as to achieve a measure of control of the therapeutic effect in the face of uncertain fluctuations in the *in vivo* environment in which drug release takes place [3]. This is usually accomplished by maximizing drug availability; however, control of drug action through formulation also implies controlling bioavailability to reduce drug absorption rates. Sustained release (SR) drug delivery system is designed to achieve prolonged therapeutic effects by continuous discharge of drug over an extended period from a single dose [4]. Thus optimal concentration of a drug at specific site will be ensured without much difficulty, often observed in conventional dosage forms. The prime flaw of all traditional dosage forms are delivering fluctuating concentration of drug in plasma, resulted over or under pharmacologic response. The users did not get proper treatment, became victim due to inherent rhythmic drug releasing problems exist in conventional dosage forms. The sustained release of a drug can be made by uniform mixing with polymers. The unique hydrophilic characteristics of hydroxypropyl methylcellulose (HPMC) derivatives strongly support development of drug-polymer solid matrix just by simple admixing with selective Methocel CR derivatives either by wet or dry granulation. It will be allowed rhythmic liberation of drugs from the solid matrix in the GIT fluids following oral administration. Thus, extended drug absorption will be achieved *in vivo* systems, ensured effective therapeutic level in the plasma to combat against diseases.

The objective of the study was to determine the extent of oral drug release efficiency of Methocel K 15M CR and Methocel K 100M CR built as proposed formulations of once daily naproxen (500 mg) SR tablet for effective management of pain related disorders.

2. Materials and methods

2.1. Materials

Naproxen was from Divis Laboratories Ltd., India; hydroxypropyl methylcellulose (Methocel K15M CR and Methocel K100M CR) was from Colorcon Asia Pvt. Ltd.; microcystalline cellulose was from Mingtai Chemical Co. Ltd., Taiwan; polyvinnyl pyrrolidone (Povidone K-30) was from BASF, Southeast Asia Pvt. Ltd.; pregelatinized starch, magnesium stearate, and talc were from Chemical Management Co., Germany; monobasic sodium phosphate, anhydrous dibasic sodium phosphate, and sodium hydroxide were from Merck, Germany.

Table 1. Proposed formulations (F1 to F8) for naproxen sustained release matrix.

Ingredients	F1	F2	F3	F4	F5	F6	F7	F8
	(mg)							
Drug	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00
Microcrystalline cellulose	31.50	54.00	31.50	54.00	20.00	-	45.00	65.00
Methocel K15M CR	182.50	146.00	-	-	36.50	35.00	30.00	30.00
Methocel K100M CR	-	-	182.50	146.00	109.50	70.00	50.00	30.00
Povidone	10.00	10.00	10.00	10.00	50.00	50.00	10.00	10.00
Pregelatinized starch	-	-	-	-	-	32.00	10.00	10.00
Magnesium stearate	6.00	6.00	6.00	6.00	6.00	5.00	5.00	5.00
Talc	-	-	-	-	8.00	8.00	-	-
Total tab wt. (mg)	730.00	730.00	730.00	730.00	730.00	700.00	650.00	650.00

Table 2. Properties of the granules for the proposal formulations (F1 to F8) of naproxen sustained release matrix tablet.

Parameters	F1	F2	F3	F4	F5	F6	F7	F8
LBD (g/ml)	0.401±0.02	0.521±0.01	0.371±0.03	0.453±0.01	0.211±0.03	0.221±0.02	0.431 ±0.02	0.412± 010
TBD (g/ml)	0.387±0.01	0.462±0.02	0.327±0.02	0.352±0.02	0.475±0.03	0.339±0.01	0.277±0.04	0.409± 0.05
Compressibility index (%)	11.15±0.03	12.58±0.02	12.49±0.03	11.17±0.01	11.45±0.01	13.35±0.02	12.21±0.04	11.17± 0.01
Total porosity (%)	32.29±0.02	26.19±0.04	29.36±0.01	34.56±0.01	26.73±0.02	34.13±0.01	31.12±0.02	30.14± 0.02
Angle of repose	22.56±0.03	24.31±0.01	22.47±0.03	29.36±0.01	24.76±0.01	21.53±0.01	23.68±0.03	21.98± 0.08
Drug content (%)	94.13±0.02	102.63±0.02	92.23±0.02	95.49±0.02	89.19±0.03	95.63±0.01	91.45±0.02	98.29± 0.01

2.2. Preparation of matrix tablet

Tablets were prepared by the method of wet granulation. The active ingredient, primary release retardants and diluents were mixed successively then made into a wet mass for granulation. The moisture content of the granules was maintained within 1.2% to 1.6%. Furthermore, secondary release retardant polymer, filler, lubricant and flow promoters were blended with dried granules, and transformed into tablets by compression at a fixed compression force (120-250 N). All the preparations were stored in airtight containers at room temperature for further study.

2.3. Physical evaluation of granules

The physical properties of granules were determined as follows:

2.3.1. Bulk density

LBD (loose bulk density) and *TBD* (tapped bulk density) were determined by 2 g of powder from each formula, previously lightly shaken to break any agglomerates formed, was placed into a 10 ml measuring cylinder. After the initial volume was observed, the cylinder was allowed to fall under its own weight onto a hard surface from the height of 2.5 cm at 2 second intervals. The reading of tapping was continued until no further change in volume was noted. Using Equations 1 and 2 [5] LBD and TBD was calculated:

LBD=Weight of the powder/volume of the packing (Equation 1)

TBD=Weight of the powder/tapping volume of the packing (Equation 2)

2.3.2. Compressibility index

The compressibility index of the granules was determined by Carr's compressibility index (Equation 3) [6].

Carr's index (%)={(*TBD*-*LBD*)×100}/*TBD* (Equation 3)

2.3.3. Total porosity

Total porosity was determined by measuring the volume occupied by a selected weight of powder (V_{bulk}) and the true volume of granules (the space occupied by the powder exclusive of spaces greater than the intermolecular space (V) (Equation 4) [7].

Porosity (%)=V_{bulk}-V/V_{bulk}×100 (Equation 4)

2.3.4. Angle of repose

The angle of repose of granules was determined by the funnel method. The accurately weighed granules were taken in a

Table 3. Properties of the matrix tablet for the proposed formulations (F1 to F8) of naproxen sustained release.

Parameters	F1	F2	F3	F4	F5	F6	F7	F8
Thickness (n=6) (mm)	4.59±0.02	4.43±0.03	4.19±0.12	4.90±0.03	4.51±0.02	4.39±0.01	4.23±0.21	4.59±0.02
Hardness (n=6) (kg/cm^2)	3.5±0.23	4.35±0.03	4.15±0.02	4.27±0.02	3.19±0.01	3.265±0.02	3.05±0.03	4.43±0.05
Friability (n=10) (%)	0.00	0.00	0.12±0.02	0.00	0.00	0.00	0.00	0.00
Weight variation test (n=20) (%)	2.153±0.02	2.903±0.23	2.342±0.01	2.528±0.03	2.503±0.01	1.132±0.02	2.44±0.02	2.19±0.03
Drug content (%)	94.13±0.02	99.293±0.03	91.23±0.02	95.19±0.01	89.12±0.02	95.69±0.01	91.15±0.02	98.15 ±0.03

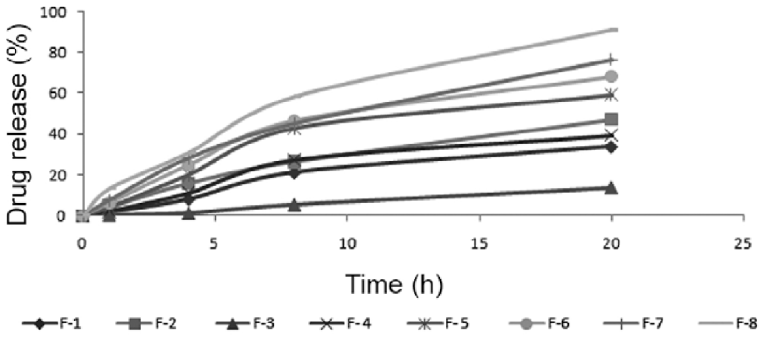

Figure 1. Effect of Methocel K15M CR and Methocel K100M CR on naproxen release from proposed formulations (F1-F8) in buffer medium (zero order Plot).

funnel. The height of the funnel was adjusted in such a way that the tip of the funnel just touched the apex of the heap of the granules. The granules were allowed to flow through the funnel freely onto the surface. The diameter of the powder cone was measured and angle of repose was calculated using the following equation (Equation 5) [8].

Angle of repose $\theta = tan^{-1}h/r$ (Equation 5)

Where, '*h*' is height of the powder cone, and '*r*' is the radius of the powder cone.

2.3.5. Drug content

An accurate amount of powdered naproxen (100 mg) was extracted with water and the solution was filtered through 0.45 µ membrane filter paper. The absorbance was measured at 278 nm after suitable dilution.

2.4. Physical evaluation of tablets

2.4.1. Hardness and friability

For each formulation, the hardness and friability of 6 tablets were determined using the Monsanto hardness tester and the Roche friabilator, respectively.

2.4.2. Thickness

The thicknesses of the tablets were determined by using a thickness gauge. Five tablets from each batch were used, and average values were calculated.

2.4.3. Weight variation test

To study weight variation, 20 tablets of each formulation were weighed using an electronic balance and the test was performed according to the official method.

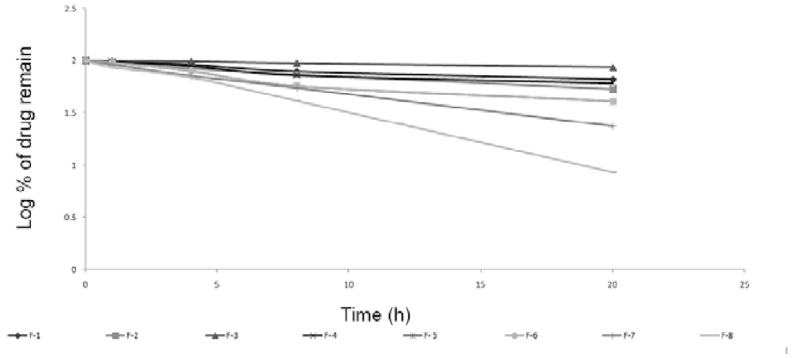

Figure 2. Effect of Methocel K15M CR and Methocel K100M CR on naproxen release from proposed formulations (F1 - F8) in buffer medium (first order Plot).

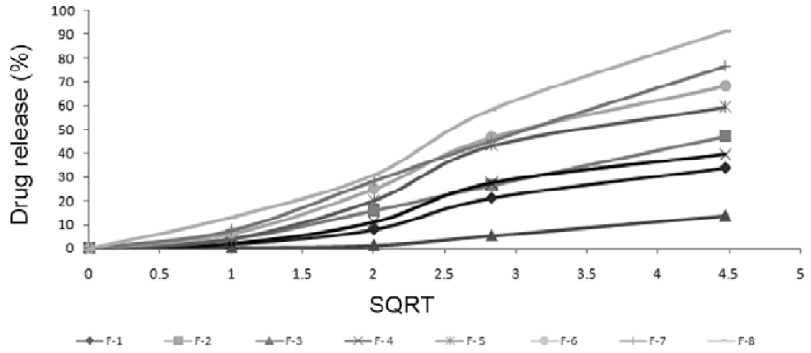

Figure 3. Effect of Methocel K15M CR and Methocel K100M CR on naproxen release from proposed formulations (F1 to F8) in buffer medium (Higuchi Plot).

2.4.2. Drug content

Five tablets were weighed individually, and the drug was extracted in water. The solution was filtered through 0.45 µ membrane filter paper. The absorbance was measured at 278 nm after suitable dilution.

2.5. Preparation of buffer medium

Dissolution medium was prepared according to USP method. It was prepared by dissolving 2.62 g of monobasic sodium phosphate and 11.50 g of anhydrous dibasic sodium phosphate into 1000 ml of water. The pH is adjusted to 7.4 with either 0.1 M sodium hydroxide or 0.1 M hydrochloric acid if necessary.

2.6. In vitro dissolution study

The *in vitro* dissolution studies were carried out using USP apparatus type II (37±5 °C, 75 rpm). The preheated medium (900 ml) was poured into each vessel, one tablet in each of the six vessels were placed. A 10 ml sample of solution was collected at the end of 1, 4, 8 and 20 h during the studies. The volume withdrawn from each vessel immediately was replaced. The drug release of different time intervals was measured at 278 nm by UV spectrophotometer (Shimadzu UV spectrophotometer, UV-1650 PC).

2.7. Drug release kinetics

The *in vitro* drug release kinetic data were tested with the following mathematical model.

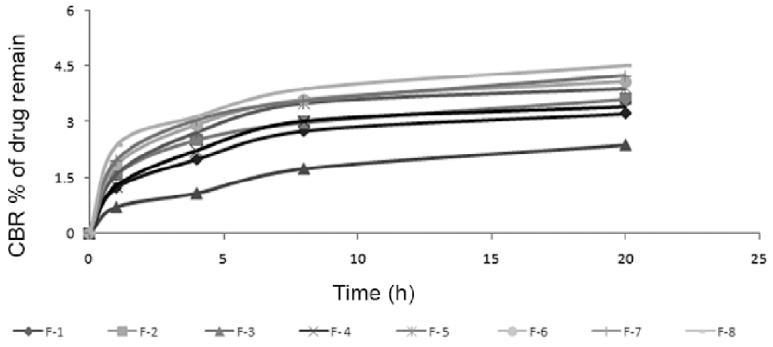

Figure 4. Effect of Methocel K15M CR and Methocel K100M CR on naproxen from proposed formulations (F1 to F8) in buffer medium (Hixson-Crowell plot).

Table 4. *In vitro* drug release profile for proposed formulations (F1 to F8) of naproxen sustained release matrix tablet.

Time interval (h)	% Drug release							
	F1	F2	F3	F4	F5	F6	F7	F8
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	1.86	3.98	0.36	2.10	4.10	6.23	7.60	13.20
4	7.94	15.92	1.27	11.06	20.17	24.94	28.36	30.95
8	21.15	26.58	5.32	27.50	43.09	46.66	45.21	58.52
20	33.80	47.17	13.62	39.55	59.38	68.19	76.58	91.46

2.7.1. Zero order equation

The equation assumes that the cumulative amount of drug release is directly related to time. The equation may be as follows (Equation 6) [9]:

$$C = K_0 t \quad \text{(Equation 6)}$$

Where, 'K_0' is the zero order rate constant expressed in unit concentration/time and 't' is the time in hour. A graph of concentration vs time would yield a straight line with a slope equal to 'K_0' and intercept the origin of the axes.

2.7.2. First order equation

The release behavior of first order equation is expressed as log cumulative percentage of drug remaining *vs.* time. The equation may as (Equation 7) [10]:

$$LogC = LogC_0 - kt / 2.303 \quad \text{(Equation 7)}$$

Where, 'C' is the amount of drug undissolved at t time, 'C_0' is drug concentration at 't'= *0*, and 'k' is the corresponding release rate constant.

2.7.3. Higuchi square root law

The Higuchi release model describes the cumulative percentage of drug release vs square root of time. The equation may as follows (Equation 8) [11]:

$$Q = K\sqrt{t} \quad \text{(Equation 8)}$$

Where, 'Q' is (100-C) the amount of drug dissolved at time 't'. 'K' is the constant reflecting the design variables of the system. Hence, drug release rate is proportional to

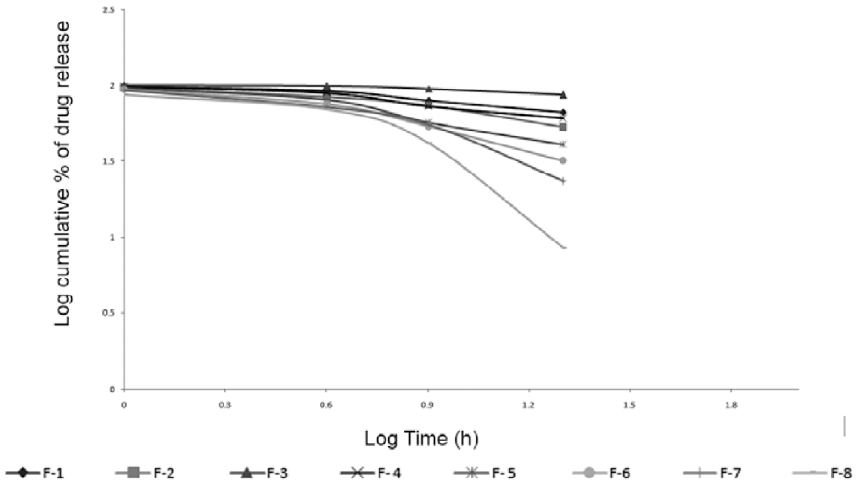

Figure 5. Effect of Methocel K15M CR and Methocel K100M CR on naproxen release from proposed formulations (F-1 to F-8) in buffer medium (Korsmeyer-Peppas Plot).

Table 5. *In vitro* drug release kinetics for proposed formulations (F1 to F8) of naproxen sustained release matrix tablet.

	Multiple coefficient (r^2)			
	Zero order	**First order**	**Higuchi**	**Hixson-Crowell**
F1	0.9470	0.9651	0.9470	0.3893
F2	0.9632	0.9899	0.9632	0.2195
F3	0.9893	0.9886	0.9893	0.1872
F4	0.9126	0.9399	0.9126	0.3661
F5	0.8926	0.9464	0.8926	0.0865
F6	0.9114	0.976	0.9114	0.4704
F7	0.9485	0.9991	0.9485	0.3253
F8	0.9382	0.9957	0.9382	0.4839

the reciprocal of the square root of time.

2.7.4. Hixson-Crowell cube root law

It is the law that represents idea about the evaluation of drug release pattern changes with the surface area and the diameter of the particles/tablets. It is mentioned as the cube root of the percentage of drug remaining in the matrix vs time. The equation may as (Equation 9) [12]:

$$Q_0^{1/3}-Q_t^{1/3}=k_{HC}\times t \quad \text{(Equation 9)}$$

Where, 'Q_0' is the initial amount of the drug in the tablets, 'Q_t' is the amount of drug release in time *'t', '*k_{HC}' is the rate constant for the Hixson-Crowell cube root law.

2.8. Release mechanism

2.8.1. Korsmeyer-Peppas equation

Korsmeyer *et al.* developed a simple, semi-empirical model, relating exponentially the drug release to the elapsed time. The equation may as follows (Equation 10) [12]:

$$Q/Q_0=Kt^n \quad \text{(Equation10)}$$

Where, 'Q/Q_0' is the fraction of drug released at time 't', 'K' is the Constant comprising the structural geometric characteristics, 'n' is the diffusion exponent that depends on the release mechanism. If $n \leq 0.5$, the release mechanism follows a Fickian diffusion, and if $0.5<n<1$, the release follows a non-Fickian diffusion or anomalous transport. The drug release follows zero order drug release and case II transport if $n=1$. But when $n>1$, then the release mechanism is super case II transport. This model is used in the polymeric dosage form when the release mechanism is unknown or more than one release phenomena is present in the preparation [14].

3. Results and discussion

In this study, tablets of all the proposed formulations (F1 to F8) were prepared from different grades of Methocel K 15M CR and Methocel K 100M CR hydrophilic polymers by wet granulation method (Table 1). These polymers were utilized alone (F1 to F4) or in combination (F5 to F8) to evaluate their ease of manufacture and extent of release retardant effects. Formulations (F1 to F2) contained Methocel K 15M CR exhibited physical problems were lowering hardness, surface cracking, and breakdown into pieces during dissolution. Similarly, formulations (F3 to F4) prepared utilizing Methocel K 100M CR showed very high hardness, capping, and difficulty in sieving and individual variation in release. However, tablets (F5 to F8) prepared from Methocel K 15M CR and Methocel K 100M CR was free from all the physical problems appeared in earlier formulations [15].

The granules of different proposed formulations (F1 to F8) were evaluated for LBD, TBD, compressibility index, total porosity, angle of repose and drug content (Table 2). The results of LBD and TBD ranged from 0.211 ± 0.03 to 0.521 ± 0.01, and

Table 6. *In vitro* drug release mechanism for proposed formulations (F1 to F8) of naproxen sustained release matrix tablet using Korsmeyer-Peppas model.

	Multiple coefficient (r^2)	Diffusion exponent (n)	Release type
F1	0.0560	0.4168	Fickian
F2	0.0802	0.5364	Non-Fickian
F3	0.0964	0.1941	Fickian
F4	0.1223	0.5183	Non-Fickian
F5	0.1052	0.2665	Fickian
F6	0.1115	0.3753	Fickian
F7	0.4338	0.1327	Fickian
F8	0.6971	0.1452	Fickian

0.277±0.04 to 0.475±0.03, respectively. The bulk densities of granules of the proposed formulation F2 were quite higher than those of other granules. This may be due to the presence of more fine granules, as water alone could not provide sufficient binding to the granules [16]. The results of compressibility index (%) ranged from 11.15±0.03 to 13.35±0.02, and 26.19±0.04 to 34.56±0.01, respectively. Generally, compressibility index values up to 15% result in good to excellent flow properties. The results of angle of repose ranged from 21.53±0.01 to 29.36±0.01. The results of angle of repose (< 30) indicate good flow properties of granules. The results of total porosity ranged from 26.19±0.04 to 34.56±0.01. The percentage porosity values of the granules ranged from 26.19 to 34.56% indicating that the packing of the granules may range from close to loose packing and also further confirming that the particles are not of greatly different sizes. Generally, a percentage porosity value below 26% shows that the particles in the powder are of greatly different sizes and a value greater than 48% shows that particles in the powder are in uniform of aggregates or flocculates. The drug content in a weighed amount of granules of all formulations ranged from 89.19±0.03 to 102.63±0.02 %. All these results indicate that the granules possessed satisfactory flow properties, compressibility and drug content [16]. The tablets of the proposed formulations (F1-F8) were subjected to various evaluation tests like thickness, hardness, weight variation test, friability and *in vitro* dissolution in buffer (pH, 7.4) (Table 3). The thickness of the tablets ranged from 4.19±0.12 to 4.59±0.02 mm (Table 3). The hardness and percentage friability of the tablets of all batches ranged from 3.05±0.03 to 4.43±0.05 kg/cm^2 and 0.00 to 0.12±0.02%, respectively. The average percentage deviation of 20 tablets of each formula was less than 5%. Drug content among different batches of tablets ranged from 89.03±0.03 to 102.6±0.02. All the formulations showed uniform thickness, weight variation and friability within Pharmacopoeial limit. Tablet obtained from formulations (F1-F2) showed lower hardness than official specification, and formulations (F3-F4) exhibited very high hardness.

The results of *in vitro* dissolution studies of formulations (F1-F8) in buffer (pH 7.4) (Table 4). Tablets F1, F2, F3, F4, F5, F6, F7 and F8 released 7.94%, 15.92%, 1.27%, 11.06%, 20.17%, 24.94%, 28.36% and 30.95% of naproxen at the end of 4 h. Tablets of formulation F8 released 58.52% and 91.46% at the end of 8 h and 20 h, respectively. Among these formulations, the release rate was increased by reducing the amount of Methocel K 100M CR, and uniform naproxen release was observed with Methocel K 15M CR-Methocel K 100M CR (1;1) ratio [17].

3.1. Proposed drug release mechanism

The drug release mechanism from these proposed formulations (F1-F8), the data were

treated to zero order, first order, Higuchi, Hixon Crowell and Korsmeyer-Peppas equation (Tables 5 and 6; Figures 1 to 5). All the formulations (except F-3) did not follow zero order release pattern. When the data were plotted according to the first order equation, the formulation showed a fair linearity, with regression values between 0.9399 to 0.9991. Release of the drug from a matrix tablet containing hydrophilic polymers generally involves factors of diffusion [18]. Diffusion is related to transport of drug from the dosage matrix into the *in vitro* study fluid depending on the concentration. As gradient varies, the drug is release, and the distance diffusion increases. This could explain why the drug diffuses at a comparatively slower rate as the distance for diffusion increases, which is referred as square-root-kinetics or Higuchi kinetics. This diffusion phenomenon of drug release from tablet matrix or granules were supported by both of the Hixon-Crowell and Korsmeyer-Peppas equation (Tables 5 and 6). All the formulations (except F2 and F4) exhibited Fickian type drug release from the tablet matrix which supported first order and Higuchi release kinetics [19].

4. Conclusion

The hydrophilic polymer matrix of Methocel K 15M CR or Methocel K 100M CR alone could not control the naproxen release effectively for 24 h. It is evident from the result that a matrix tablet prepared with mixture of Methocel K 15M CR or Methocel K 100M CR (1:1) ratio is a better system for once daily sustained release of naproxen. The best proposed formulation, F8 may be used for the development of naproxen sustained release matrix, to meet the patient's demand for management of various inflammatory diseases.

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