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DEVELOPMENT, OPTIMIZATION AND EVALUATION OF GUAR GUM AND SCMC BASED IPN HYDROGEL BEADS FOR CONTROLLED DRUG DELIVERY OF CAPTOPRIL

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ABSTRACT
Interpenetrating polymeric networks hydrogel beads of guar and sodium carboxy methyl cellulose (SCMC) containing captopril, an angiotensin converting enzyme inhibitor were prepared by single water in water emulsion Gelation technique using AlC3 as a cross-linker. Various formulations were prepared by altering the polymer ratio, concentration of cross-linker, and curing time for bead preparation. The IPN hydrogel beads formulations were optimized, developed and evaluated successfully by Fourier transform Infra-red (FTIR) & scanning electron microscopy (SEM). From the prepared formulation it was found that the beads were spherical in shape and were free flowing. The prepared beads showed elevated drug encapsulation efficiency along with extended release of drug in intestine. Maximum % drug encapsulation efficiency was found to be 85.43 ± 0.074, where as the swelling studies showed that prepared beads are pH sensitive and it has a high ability to swell in alkaline medium as compared to acidic medium. The resultant value from swelling studies showed that as the concentration of cross linker increases, water uptake capacity has decreases. Also percentage cumulative drug release was performed in both acidic and basic medium. The results demonstrate that only 13.49% to 24.84% drug was released in acidic medium pH(1.2), whereas 58.56% to 87.34% drug was released in alkaline medium pH(7.4) within 10 hours of study. Finally from power plotting of drug release it was found that the formulations showed zero order release kinetic and the release of drug IPN hydrogel beads followed Non-Fickian type transport mechanism. The results of all formulations, indicates that the drug releases in acidic medium was decreases and increases in alkaline medium which would help to minimize the gastric side effects of captopril.

KEYWORDS: captopril; guar gum; SCMC; cross-linker; emulsion Gelation method.

1. INTRODUCTION
Most widely used, route of administration is Oral drug delivery system. Pharmaceutical products are designed for oral delivery is mostly the immediate release and faster action of drug. But several disadvantages with oral drug delivery systems like not suitable in emergency, non-convenient for GI disorders, psychiatric disorders, etc. to overcome these problems regulatory approved controlled release drug delivery system is developed which constantly releases drug over a longer period of time.[1]

In recent years many polymers have been widely used to developed controlled release formulations for those drugs which having a very short half-life. Among these problems hydrophilic biopolymers are more suitable for oral administrations. The biocompatible and biodegradable polymer is safe and regularly used in pharmaceutical applications because of their ability to form cross linked three dimensional networks hydrogel. And these hydrogel can swells in biological fluids or in water.[2] For achieving a controlled release of drug IPN hydrogel beads to be better approaches.

In recent decades, hydrogel have been largely used as a smart biomaterial because of its better physical and chemical properties it is broadly used in tissue engineering and in drug release application. Hydrogel are actually 3D-"solid like solution" material s which having an ability to absorb in a large amount of water for maintaining their dimensional stability. hydrogel are enough to respond in environmental stimuli fluctuations

such as temperature PH electrical field, ionic strength and presence of enzymes.[3] according to the condition they may be swell or shrinked in the swollen state hydrogel are rubbery and soft.

Hydrogel are classified according to their method of preparation, origin of hydrogel, ionic strength swelling nature, degradation rate, and cross linking nature. one of the major importance in this classification is based on their cross-linking nature and method of preparation (physical & chemical)are, co-, homo, interpenetrating polymers.[4] Chemical hydrogel are the type of hydrogel where the chains are linked with weak bonds such as hydrogen bonds, electrostatic bonds.[5] IPN term firstly introduced by Miller in 1960s.[6] Interpenetrating polymers or networks (IPN)are generally formed of two or more polymers networks that may be cross linked by physical or chemical bonds, where two or more networks which are partially inter placed on a polymer scale but not bonded covalently with each other. The networks cannot be separated unless chemical bonds are broken (IUPAC Definition). IPN can be formed simultaneously (from monomer A & B) or sequentially (from polymer A & B). two types of IPNs are there-full IPN and semi IPN in full IPN both networks cross linked or in semi IPN only one networks is cross linked. So, the advantages of IPN in the development of hydrogel lie in the sharing properties of combination networks.[7]

2. MATERIAL AND METHODS

2.1. Materials

Captopril was kindly received as a gift sample by Rusan Parma ltd. (Dehradun, India). All other Analytical reagents like AlCl3 as a cross-linker, and Tween 80 as a plasticizer was available in college with A grade "from central drug house pvt. Ltd", Double distilled water was used throughout the work.

2.2. Optimization Study

The selection of polymer or their concentration was successfully done. Firstly I made 1% w/v for the selection of ratio of polymers, which made no proper gel (viscosity was not in gel). then I made 1.5% w/v polymer concentration over gel. From then on, I made 2%; which made proper gel with proper viscosity. I took cacl2 as a cross linker but light yellow colored beads appeared in cacl2. Then I took AlCl3 as a cross linker; beads were successfully prepared in an off white color.

2.3 Preparation of blank IPN beads

The total concentration of polymer was fixed at 2%w/v after optimization. Different. In an aqueous solution ratios of guar gum and scmc was dispersed and homogenized using a magnetic stirrer. The resulting gum solution was drop wise added through a 21-gauge flat-tipped hypodermic needle into 100ml of aqueous metallic salt solution of AlCl3 which contains small concentration of Tween 80. Prepared beads were cured for 30 min. the beads were collected after filtration, three times washed with distilled water and dried in a hot air oven at 37^0c till constant weight obtained and then for complete evaporation of solvents beads were kept in a vacuum desiccators.

2.4. Preparation of drug loaded IPN Beads

Guar gum: sodium carboxy methyl cellulose IPN beads containing captopril were prepared by single w/w emulsion Gelation method in a completely aqueous environment. Calculated amount of captopril (30%w/w) was dispersed homogenously in an aqueous polymeric solution. the dispersion was drop wise added through a 21 gauze flat tipped hypodermic needle into slightly agitated 100ml of aqueous AlCl3 solution containing small concentration of Tween 80.

beads were filtered and washed three time using distilled water(100ml) and subsequently dried at 37^0c in hot air oven. Finally for complete evaporation of solvents, beads were kept in vacuum desiccators until used. Different IPN beads were prepared by different polymer ratios, curing time and cross linkers. The composition of IPN beads along with variations is showed in table no.1.

Table: 1 composition table of formulation from F1-F6

Sample code	Polymer concentration (%w/v)	Polymer ratio (guar gum + scmc)	Drug loading (%w/w)	Conc. of Alcl3	Tween 80 (%w/v)	Gelation time(min)
F1	2%	1:1	30	4	0.2	30
F2	2%	1:2	30	6	0.2	60
F3	2%	1:1	30	4	0.2	30
F4	2%	1:2	30	4	0.2	30
F5	2%	1:1	30	6	0.2	60
F6	2%	1:2	30	4	0.2	30

2.5. Surface morphology analysis

Drug loaded guar gum and SCMC blend hydrogel beads were examined under a SEM photographs were taken at different magnification like 60X, 200X with 18 kV voltage and 1.00mm Hg pressure. The sample was placed on adhesive paper and photographs were taken.

2.6. Bead size analysis

The size of dried IPN hydrogel beads was measured using an optical microscope. To calibrate the eyepiece micrometer, a standard stage micrometer was used. Dried beads were placed in a glass slide and the number of divisions of the calibrated eyepiece was counted. A hundred beads were randomly selected from each

formulation and the individual particle diameter was calculated based on this formula:

$$1\ \text{eyepiece micrometer division} = \frac{\text{number of stage micrometer divisions}}{\text{number of eyepiece micrometer division}} \times 10\ \text{mm}$$

2.7. Determination of percentage yield

The percentage yield value of the prepared formulations was calculated as a percentage of the total concentration of polymers and drug used during the preparation of formulations. The percentage yield of the beads was calculated using the formula:

$$\text{Production yield (\%)} = \frac{\text{Total amount of prepared beads}}{\text{Amount of drug + total amount of polymers}} \times 100$$

1.8. Determination of drug entrapment efficiency

The drug content in the captopril loaded guar gum and sodium carboxymethyl cellulose IPN beads was quantitatively evaluated by immersing the required amount of dried beads in phosphate buffer saline (pH 7.4) to dissolve the drug dispersed inside the beads and the solution was stirred with help of a magnetic stirrer for about 10 hours to release the entrapped drug. After that, the suspension was filtered using filter paper and the filtrate was diluted and analyzed for the ibuprofen content using Shimadzu (UV-1800) UV-Visible spectrophotometer at 205 nm wave length. The amount of captopril present in the beads was determined using a calibration curve. The entrapment efficiency was determined for all batches using following equation:

$$\text{Drug entrapment efficiency (\%)} = \frac{\text{Experimental drug content}}{\text{Theoretical drug content}} \times 100$$

2.9. Determination of flow properties

Flow properties of drug -loaded beads can be assessed by measuring its Carr's index and Hausner ratio. Carr's index and the closely related Hausner ratio have become the simple, fast and popular methods of predicting flow characteristics. The Carr's index has been proposed as an indirect measure of bulk density, size and shape, surface area, moisture content and cohesiveness of materials because all of these can influence the observed Carr's index. Carr's index and Hausner ratio are determined by measuring both the bulk volume and the tapped volume of a powder.

The bulk and tapped densities were measured in a 100 ml graduated measuring cylinder. The sample contained in the measuring cylinder was placed in a USP-I tap density test apparatus. At first, 500 taps were applied, and the tapped volume was noted. The tapped volume was measured once again following additional 750 taps. From the initial bulk volume and final tapped volume, respective densities were calculated. Carr's index was determined by the following formula:

$$\text{Carr's Index} = \frac{\text{tapped density} - \text{bulk density}}{\text{tapped density}} \times 100$$

Hausner ratio was determined by the following formula:

$$\text{Hausner ratio} = \frac{\text{tapped density}}{\text{bulk density}}$$

2.10. Angle of Repose

Angle of repose is a characteristic related to inter sparticulate friction or resistance to movement between particles. The angle of repose was measured using the fixed height funnel method. Then weighed sample was taken in a funnel. The height of the funnel was adjusted in such a way so that the tip of the funnel just touches apex of the heap of the sample. The sample was allowed to flow freely through the funnel on to the surface. The height and diameter of the sample cone was measured and angle of repose was calculated. Angle of repose was determined by following formula:

$$\text{Angle of repose} = \tan^{-1}\frac{h}{r}$$

Where h= height of the cone
r= radius of the cone

2.11. Solubility study

The solubility of drug captopril was determined in water, phosphate buffer pH 1.2,7.4. The small amount of solvent (approx.10 ml) was added in a beaker. to make a saturated solution small concentration of drug was also dissolved, now with magnetic stirrer the solution was stirred for 1-2 hours for complete solubilization. After that from beaker 1 ml of pipette out and necessary dilution was made at the last by using uv-spectrophotometer absorbance was determined against with an appropriate.

2.12. *In-vitro* drug release study

In-vitro drug release study of drug captopril were evaluating in phosphate buffer pH 1.2 and in alkaline medium phosphate buffer pH 7.4 in USP dissolution apparatus using 37 ± 1^0c using USP paddle type apparatus. Beads were immersed in 900 ml of the respective medium and stirred at 50 rpm. In every hour sample was taken and diluted for further assayed in uv-spectrophotometer at 205 nm.

3. RESULT AND DISCUSSION

3.1.1 Physical Characteristics of drug

Color: white to off-white crystalline powder
Odor: slight sulfurous
Taste: bitter
Melting point: $107\text{-}110^0$ (reported 104- 110^0c according to I.P 2010)

3.1.2. Solubility Studies

Solubility of drug-captopril was determined in aqueous and different non-aqueous solvents showed in Table: 2. The results determined that the captopril is soluble in aqueous as well as in non-aqueous solvents hence it is both lipophillic and hydrophilic in nature.

Table 2: Solubility profile of Captopril

S. No.	Solvents	Solubility
1	Distilled Water	Freely soluble
2	0.1 N HCL (pH 1.2)	soluble
3	Phosphate buffer saline (pH7.4)	soluble
4	Ethanol	soluble

3.1.3. Partition Coefficient

the partition coefficient of captopril in phosphate buffer pH 7.4 was determined by using equal amount of n-octanol as a oil phase and phosphate buffer pH 7.4 as the aqueous phase. Result showed that partition coefficient of captopril in phosphate buffer pH 7.4 was found to be 0.95±1.21 which also demonstrate the lipophillic and hydrophilic nature of the drug. guar gum and SCMC in aqueous gelling medium containing different concentration of trivalent Al^{+3} ions. Guar gum and SCMC were choosing for the preparation of IPN blend because of their high gelling ability.

Fig. 1: Drug loaded IPN Hydrogel beads in AlCl3 (cross linker) solution during Curing

Fig. 2: Drug loaded IPN Hydrogel beads after curing

3.2. Characterization of Beads

FTIR spectra of SCMC and Guar gum showed sharp peaks at 3412.89, 2924.94, 1644.33, 1420.38, 1023.79, 526.02 due to the OH stretching vibrations, C-H stretching vibrations, C=O stretching vibrations, C-H bending vibrations, C-O stretching vibrations, C-H stretching vibrations. And the drug captopril showed that the principle IR peaks at 3474.55, 1589.96, 1080.31, 1747.9, 798.76, 1747.91 due to OH stretching, N-H bending, C=O bending, -COO stretching, C-H stretching, C=O stretching. All the principle peaks were present in drug loaded hydrogel networks beads with minor differences in frequencies, which confirm that there was no interaction between drug and polymers.

Formation of hydrogel network structure was verified by FTIR spectrum of blank hydrogel beads showed peaks at 1618.35, 3415.56 cm^{-1} for asymmetric carboxyl ate anions and 3415.56 for the hydroxyl group. The shifts in bands in drug loaded beads confirm the formation of blend between the two polymers and Al^{3+} ions through physical cross-linking. These results suggest the formation of hydrogel networks structure wherein both the polymers were present in cross-linked conditions.

3.3. FTIR Spectroscopy

3.3.1 Identification of drug and polymer through FTIR spectroscopy

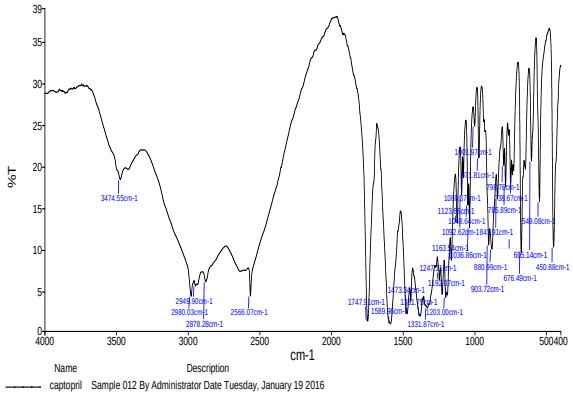

Fig. 3: FTIR Spectra of drug captopril

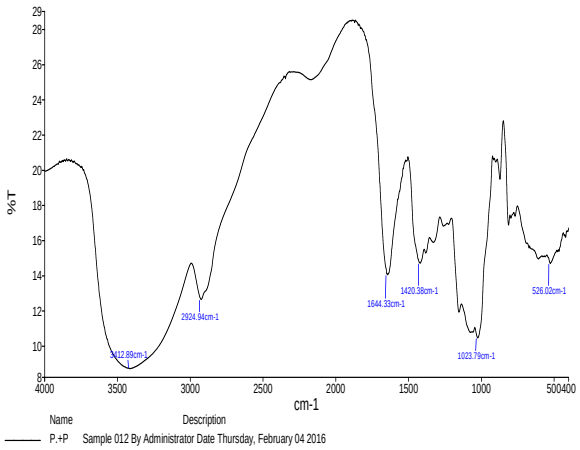

Fig. 4 FTIR Spectra of polymer (SCMC and Guar Gum)

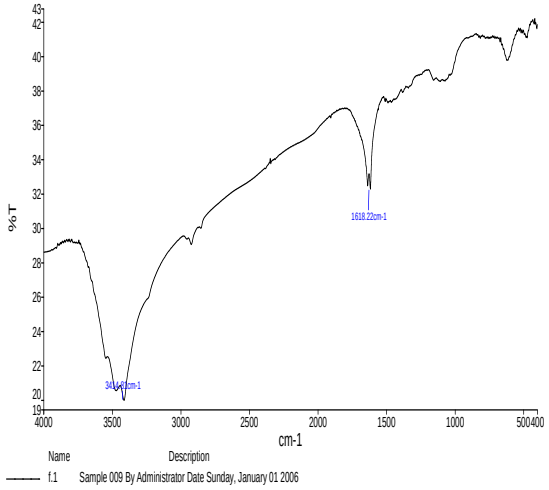

Fig. 5: FTIR Spectra of drug loaded beads

3.3.2 SEM Analysis

SEM photographs of blank and drug loaded IPN hydrogel beads were taken at different magnifications which were shown in Fig. 6 to Fig. 10 in Fig. 7, SEM photograph of blank bead showed that the beads were shortly spherical in shape and less rigid than drug loaded IPN hydrogel beads. Drug loaded beads were exactly spherical in appearance and the surface of beads was slightly rough. The effect of cross-linker concentration (4-6%w/v) (F1, F3, F5) and their curing time on the properties of beads like size, shape and morphology were studied. It was found that, as the concentration of $AlCl_3$ was increased, the spherical shape of beads were more spherical (Fig. 7, Fig. 9, Fig. 10). It was also noticeable, if the Curing time increases from 30 to 60 min, the Regidization and morphology of the beads (F2, F6) improved very well, shows in Fig: 7 and 10.

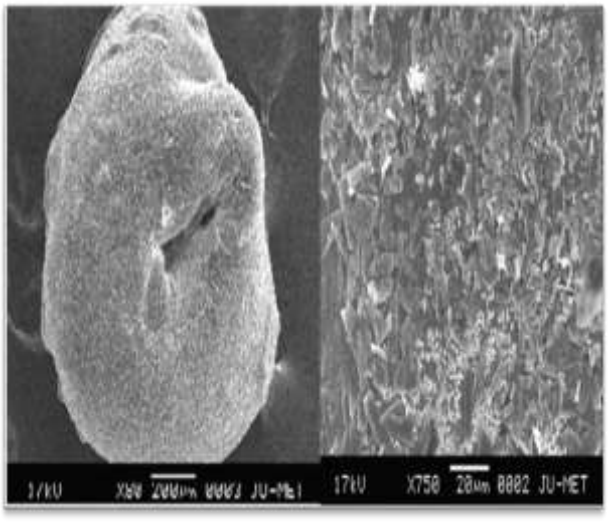

Fig. 6 SEM Photograph of blank beads

(G-a) At magnification 80X and a diameter of 200µm.
(G-b) Matrix structure at magnification 750X and a diameter of 20µm.

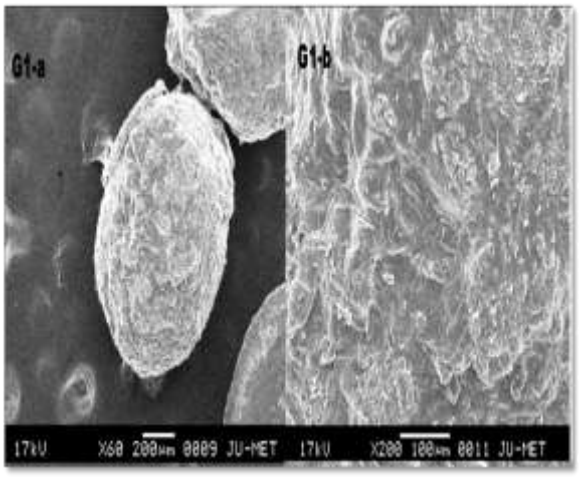

Fig. 7 SEM Photograph of Formulation F1

(G1-a) At magnification 60X and a diameter of 200µm.
(G1- b) Matrix structure at magnification 200X and a diameter of 100µm.

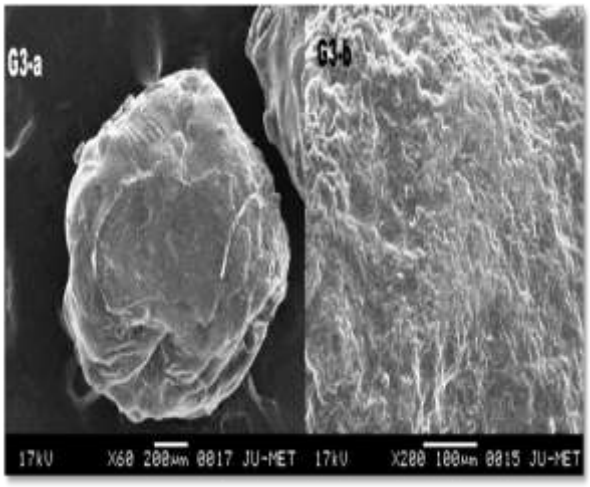

Fig. 8: SEM Photograph Formulation F3

(G3-a) At magnification 60X and a diameter of 200µm.
(G3-b) Matrix structure at magnification 200X and a diameter of 100µm.

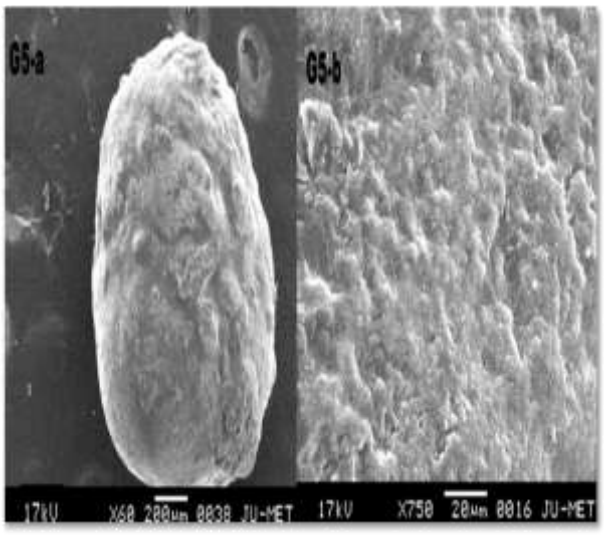

Fig. 9: SEM Photograph Formulation F5

(G5-a) At magnification 60X and a diameter of 200µm.
(G5-b) Matrix structure at magnification 750X and a diameter of 20µm.

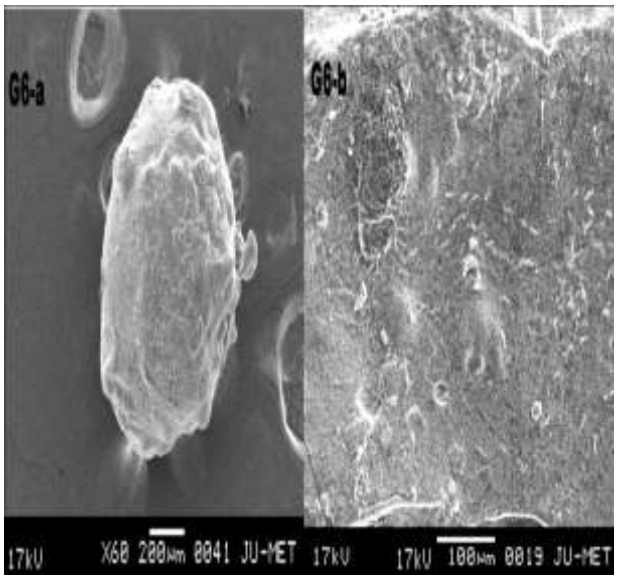

Fig. 3.10 SEM Photograph Formulation F6

(G6-a) At magnification 60X and a diameter of 200µm.
(G6-b) Matrix structure at magnification 200X and a diameter of 100µm.

3.4. Percentage (%) Yield

The percentage yield of drug (captopril) loaded beads was found in the range from 86.76% to 96.30% and is shown in Table 3. It was observes that either by altering the polymer ratio and concentration of cross-linking agent, the percentage yield was not so much varied.

3.5. Size Analysis of Bead

Particle size analysis of beads is shown in Table 3. Particles size of beads were found generally in spherical shape and the size was ranging from 3.15 x 10^3 ± 0.04 µm to 5.10 x 10^3 ± 0.07 µm. It was observed that the particle size of beads was influence by varying the polymer ratio, curing time and cross-linker concentration. Increase in concentration of cross-linker ($AlCl_{3)}$ leads to decrease in particle size.

This suggests that, during cross-linking, the polymeric network has undergone rapid shrinking leads to the formation of smaller and rigid particles at higher concentration of cross linker. It was also observed that in the polymer blend, particle size was increases, when the ratio of SCMC increased.

Table 3: Results of Micromeretic property

Formulation code	Micromeretic Property		
	Carr's index ± S.D.	Hausner ratio ± S.D.	Angle of Repose ± S.D.
F1	16.61 ± 0.37	1.62 ± 0.06	24.68 ± 0.88
F2	14.58 ± 0.238	1.21 ± 0.02	21.49 ± 1.11
F3	18.66 ± 0.275	1.12 ± 0.01	26.44± 0.60
F4	16.43 ± 0.437	1.19 ± 0.01	25.11± 2.52
F5	17.07 ± 0.257	1.35 ± 0.02	24.63 ± 0.20
F6	18.34 ± 0.22	1.21 ± 0.04	17.83± 0.29

3.6. Percentage Drug Entrapment Efficiency

The percent of drug entrapment efficiency was found to be in the range between 74.65 ± 0.35 and 85.43333 ± 0.074 (Table 4). Drug entrapment efficiency is largely depends on the curing time, concentration of SCMC and $AlCl_3$. It was observed that the encapsulation efficiency of drug was increases by increasing the concentration of cross-linker. This is because of higher extent of cross-linking, results in the formation of a more rigid network structure, which on during bead formation reduces the leaching out possibilities of the drug .and the final Results showed that IPN beads were prepare with a higher amount of SCMC exhibited lower drug entrapment efficiency. It was also examined that the entrapment efficiency was decreases by increase in the curing time of beads.

Table 4: Outcome of percentage yield, Arithmetic mean diameter, drug entrapment efficiency

Formulation code	% Yield	Arithmetic mean diameter (x 10^3 µm) ± S.D.	Entrapment Efficiency* (%) ± S.D.
F1	96.30	4.65 ± 0.09	74.65± 0.35
F2	91.35	5.10 ± 0.07	80.48±0.042
F3	86.76	4.30± 0.02	79.53 ± 0.026
F4	90.68	4.75 ± 0.11	80.68 ± 0.499
F5	94.74	3.15 ± 0.04	77.38 ± 0.278
F6	93.20	5.05± 0.06	85.43 ± 0.074

*** n=3.**

3.7. Swelling Studies

Almost all pH sensitive polymers included acidic group, such as carboxylic and sulphonic acids, or basic groups such as ammonium salts, that either gained or release protons in response to changes in environmental pH The presence of methyl and –OH group in guar gum and carboxylic groups in SCMC makes the structure of pH sensitive IPN hydrogel beads. These groups in acidic solution remain protonated and drawn in insignificant electrostatic repulsive force and result were the beads swell to a very lesser distend; But the ionic groups are de-protonated at higher pH value. At the last the Result showed that IPN hydrogel beads shows greater swelling at low concentration of cross-linker, but as the concentration was increases from 4% to 6% the swelling of IPN hydrogel was decreased. It was observed that the swelling of beads decreases when increase in the curing time of beads. This is because the pore volume of the matrix decreases with increases in curing time of beads. also it was observed that formulations which contained higher amounts of SCMC showed higher swelling properties. This may be due to the lipophillic and hydrophilic nature of SCMC, by which the water uptake capacity was also high.

Table 5: Results of swelling properties

Formulation Code	Equilibrium swelling* (%)	
	pH 1.2	pH 7.4
G1	178.33 ± 1.69	637.33 ± 1.69
G2	161.33 ± 1.24	651 ± 2.160
G3	106.33 ± 2.62	581.66± 2.35
G4	212.66 ± 2.05	553.33 ± 1.24
G5	125.33 ± 1.08	361 ± 0.816
G6	118 ± 1.63	411.66 ± 1.24

*** n=3.**

3.8. Drug Release Study

In the pH 1.2 and pH 7.4, *In vitro* drug release studies were performed and cumulative drug release in percentage versus time data were presented in Fig 11-16. The effect of the curing time and the concentration of $AlCl_3$ on the release profiles of the drug were studied. In acidic medium (pH 1.2) the concentration of drug released was very less, but in alkaline medium (pH 7.4), the concentration of drug release increased significantly. The result showed that the percentage cumulative drug released in pH 7.4 phosphate buffers was found to be maximum 87.34% from formulation F2 because of high concentration of cross-linker or curing time and minimum about 58.56% from F5 formulation within 10 hours. Where as in phosphate buffer pH 1.2 maximum release was found to be 24.82% from formulation F2 (table 6) and 13.47% minimum release from formulation F6 (table 4.9) within 10 hours because these formulations contains lesser amount of cross-linking agent and curing time from rest of all .In pH 7.4, F2 formulation shows higher concentration of drug release in comparison to F1 because of the high amount of SCMC contains in formulation F1. From these results it was examined that the release of drug decreases constantly with increase in curing time. In phosphate buffer pH 7.4, Formulations F1, F3 &F5 having same composition, but showed different percentage of cumulative drug released because of varying in concentration of cross-linker or difference in curing time. Higher curing time takes more time for cross-linking, which leads to slower rate of drug release. Formulation which contained lesser concentration of cross-linker (4% w/v $AlCl_3$) showed a higher release rate when compared to the formulations containing higher concentration of cross-linker. Also the % drug release was slower in both the dissolution media (pH 1.2 and pH7.4) for those formulations in which cross-linker was used in higher amount (6% w/v from 4%w/v). Formulations F1, F3and G5 have same composition, but only the difference in cumulative percentage of drug released was due to the difference in concentration of cross-linking agent.

Drug Release in Alkaline Media (Phosphate Buffer Solution pH 7.4) shows in fig.11 to fig.16.

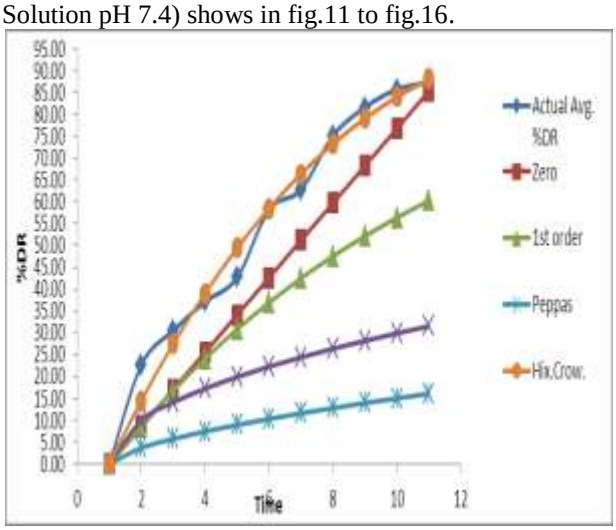

Fig.3.11: *In-vitro* release study of F1 formulation in basic medium in phosphate buffer (pH 7.4)

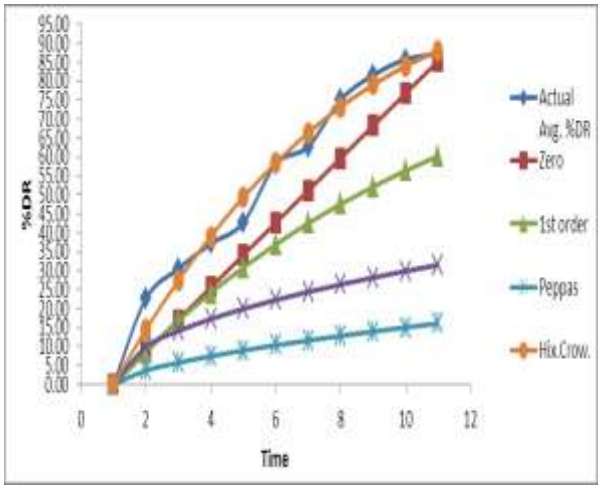

Fig. 4.12: *In-vitro* release study of F2 formulation in basic medium in phosphate buffer (pH 7.4).

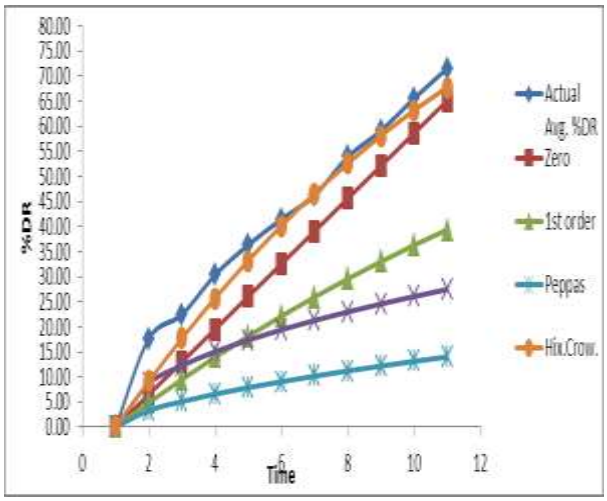

Fig. 3.13: *In-vitro* release study of F3 formulation in basic medium in phosphate buffer (pH 7.4)

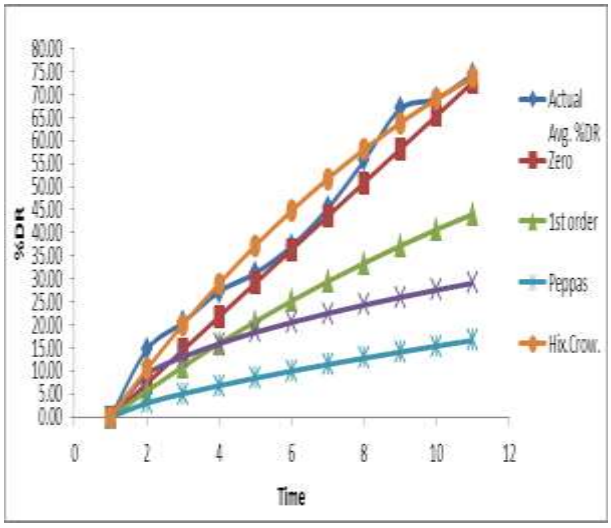

Fig. 3.14: *In-vitro* release study of F4 formulation in basic medium in phosphate buffer (pH 7.4)

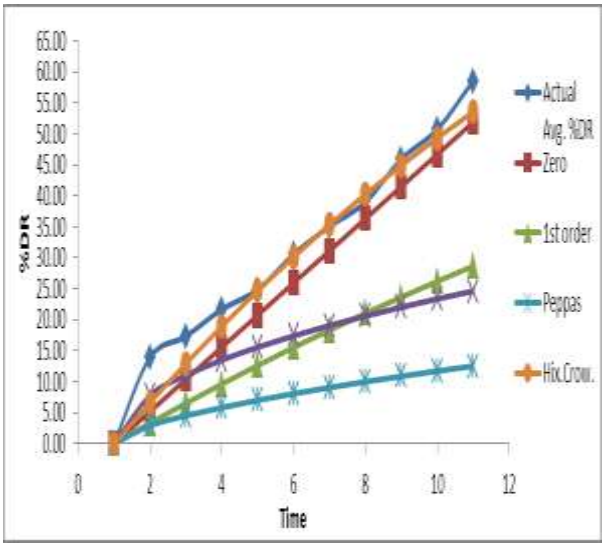

Fig. 3.15: *In-vitro* release study of F5 formulation in basic medium in phosphate buffer (pH 7.4)

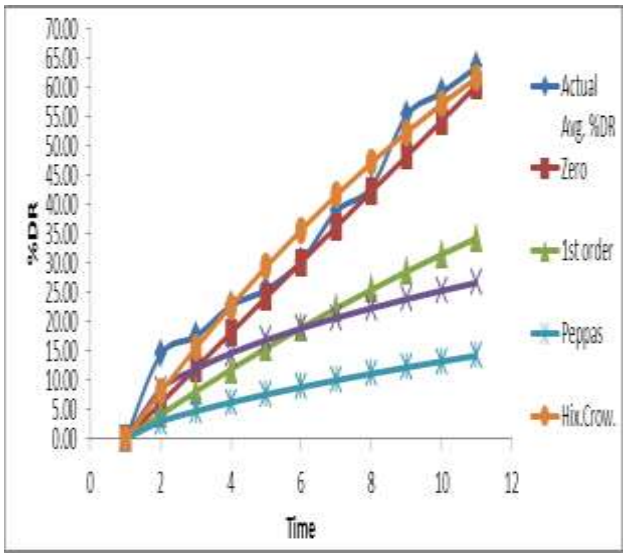

Fig. 3.16: *In-vitro* release study of F6 formulation in basic medium in phosphate buffer (pH 7.4)

3.12 Power plotting of Drug Release Data

Drug release data from the power plotting indicates that the formulations showed zero order release kinetic (Table.6) and this was suggested that the release rate of drug largely independent of the concentration of dissolved species. From Korsemeyer–Peppas equation, value of 'n' was calculated in range between 0.633 to 0.993. In case of alkaline media indicating that the drug mechanism release from the IPN hydrogel beads followed non-Fickian release kinetics and range in between 0.864 to 0.989 was found in case of acidic media indicating that the drug release mechanism followed non-Fickian release kinetic from the IPN hydrogel beads.

Table 6: Release kinetic data of formulations F1-F6 in alkaline media {(phosphate buffer solution (pH 7.4)}

Formulation code	Zero order	First order	Higuchi kinetic	Hixson Crowell	Korsemeyer Peppas		Best fit model	Mechanism of release
	R^2	R^2	R^2	R^2	n	R^2		
F1	0.977	0.980	0.913	0.992	0.993	0.745	Peppas Korsmeyer	Anomalous Transport
F2	0.967	0.971	0.908	0.985	0.639	0.973	Hixon-Crowell	Anomalous Transport
F3	0.980	0.981	0.903	0.989	0.626	0.982	Hixon-Crowell	Anomalous Transport
F4	0.986	0.959	0.904	0.975	0.741	0.970	Zero order	Anomalous Transport
F5	0.982	0.968	0.896	0.977	0.633	0.956	Zero order	Anomalous Transport
F6	0.981	0.958	0.898	0.970	0.688	0.937	Zero order	Anomalous Transport

CONCLUSION

The IPN hydrogel beads of captopril by using natural polymer guar gum and synthetic polymer sodium carboxy methyl cellulose for controlled drug delivery system were prepared successfully. FTIR and SEM analysis were used to confirm the formation of IPN structure. Other Evaluations of all the formulations were analytically done. By observing the obtained results it was found that drug release follows non-Fickian type behavior. It is demonstrated that the IPN hydrogel beads were useful for controlling the release of drug in acidic medium and increases in alkaline medium and the gastric side effects of drugs will be reduce.

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