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# PREPARATION AND ASSESSMENT OF PHARMACEUTICAL HYDROGELS OF CIPROFLOXACIN BY USING POLYMERS

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## Abstract

The main goal of this assessment was to create pH-responsive hydrogels formulation using polymers. For the controlled distribution of Ciprofloxacin (CPX), which is intended for release in the duodenum, hydrogels formulations were created. Formulations that have been evaluated in vitro for their chemical compatibility with the loaded drug, gel-matrix morphology, swelleability, and drug release kinetics. All of the formulations offered swelleability and pH-dependent drug release. With a very low quantity of the drug releasing at the pH equivalent to that of stomach pH, designing was based on a blend of derived and natural polymers, demonstrated prolonged stable drug release at the pH of the duodenum. Diffusion was the main methods that contributed to the release of drugs. FTIR study showed no drug-gel interaction, and SEM analysis showed that the gel matrix had a porous surface with linked tunnels. The interconnected tunnel structure may contribute to the diffusion of drug molecules and aqueous media. This assessment confirmed about hypothesis demonstrated on the development of pH-responsive extended release of drug delivery system for the hydrophilic and the lipophilic drugs as well, benefited greatly from the use of both natural and synthetic gum, the small intestine being the primary site of absorption. Future studies should concentrate on pharmacokinetic profiling and cytotoxic analysis of drugs loaded in pH-responsive hydrogels.

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## INTRODUCTION

More than any other subject, medicine has advanced in chemistry, pharmacology, and clinical research throughout the past century. The development of genomic sciences has significant influence of the identification of drugs and their effects (Drew, 2000). The perfect system should be able to be provided at the site of action and have the ability to be given as a single dose throughout the duration of the therapy (Grassi, *et al.,* 2014). Long-term release, controlled release, and sustained release therapies have been created for this reason, ensuring that patients have access to the active ingredients for a longer amount of time following dosage form administration. Medicine therapy is extended when using a sustained released dose form, as the medicine is released over a period of 12 to 24 hours. It is used to keep the plasma level below the threshold of toxicity for an extended amount of time in a variety of acute and chronic diseases. (Uhrich, *et al.,* 1999). There are currently several different kinds of continued release quantity methods in use that remained recognized (Wadher, *et al.,* 2011). The term "hydrogels" first appeared in a piece of writing in 1894. In any case, the substance mentioned there was actually a colloidal gel created with inorganic salts rather than hydrogels as we know it today. It is noteworthy to observe that the term's history has been continuously lengthy (Seow, *et al.,* 2014). Hydrogels are the complex system polymers made by hydrophilic compounds which may absorbs great amount of water or the biological fluids. Due to existence of physical crosslinks like crystallites or entanglements, or chemical crosslinks like tie-points and junctions, the networks, which are made up of homo polymers or copolymers, are insoluble. In any case, a poly hydroxyl ethyl methacrylate (pHEMA) hydrogels. Hydrogels are, in fact, the first materials that created with the patient's needs in mind. Since then, there have been an increasing number of investigations on hydrogels for use in

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biomedical applications, particularly during the 1970s. Over the years, the objectives and scope, as well as the quantity of materials, have continuously expanded and altered. (Lee, *et al.,* 2013).

It is also anticipated that hydrogels in a variety of applications would get smaller in the era of nanofabrication (Drexler, *et al.,* 1992). The separation of proteins is a common use for gel electrophoresis as well as DNA. A recent study revealed that a little electrophoresis gel device used. It was built to measure 25 mm in length and 50 μπι in width. The gels that are employed in the device are orders of magnitude smaller than the gels utilized in traditional instruments. Hydrogels miniaturization is crucial for all the regions previously mentioned. For instance, the capacity to consistently make hydrogels in the manufacture of glucose micro sensors requires a microscale. Although hydrogels are often biocompatible, they are not ideal biomaterials; that is to say, they continue to elicit unwanted bodily reactions. (Pishko, *et al.,* 1991).

One of the newest fluorinated quinolone antibiotics is ciprofloxacin, a derivative of quinolone carboxylic acid. used in clinical settings to treat a variety of bacterial diseases, such as community-acquired pneumonia, some skin, bone, and soft tissue infections, and upper and lower respiratory infections and have been suggested by the World Health Organization (WHO) as second-line treatments for tuberculosis (TB), primarily in cases where first-line anti-TB therapy has been ineffective or resistant. Derivatives of ciprofloxacin have therefore consistently piqued curiosity. Over the past 30years, a number of ciprofloxacin derivatives have been developed that have demonstrated a variety of biotic properties, including anti-TB, antifungal, anti-HIV, antibacterial, anti-ischemic, anti-malarial, anti-tumor, anti-oxidation, and inhibitory imaging profiles. (Tevyashova, *et al.,* 2015).

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Polymers can have a natural, synthetic, or mixed origin. Stability of the backbone. Polymers may be biodegradable or non-biodegradable. It may consist of polymers, proteins, or derivatives of cellulose. it can be either hydrophilic or hydrophobic. (Bansal, *et al,.* 2013) Polymers are effective binders because they can influence the drug's release rate from the dose and have good flow characteristics. Its effects vary depending on the dose form. For example, capsules work well as fillers and tend to make preparations bulkier. Polymers act as mucoadhesives on the stomach lining in modified release dose forms, which serves to prolong the stomach retention period (Felt *et al.*,1998).

## Materials & Methods

Ciprofloxacin, Eu-S100, Ammonium persulfate, Acrylic acid, Xanthan gum, N. N-methylene bis-acrylamide, Ultra Voilet visible spectrophotometer CE7200, FTIR, pH meter, DSC, Hot Oven.

## Designing

According to the researchers' study, hydrogels was created using the free-radical polymerization technique (Mahmood *et al.*, 2019). Table 1 provides information on the gel composition. In short, a magnetic stirrer was used to dissolve XG and Eu-S100 separately or together in a pH-neutral aqueous solution for 30 minutes at $37^0$C. The reaction mixture's pH reached the basic level. The APS (Initiator) was dissolved in room temperature distilled water in a different beaker. Distilled water was used to disperse MBA (cross-linking) in the third beaker. After a half-hour of constant stirring at room temperature, the dispersion (XG, Eu-S100, or both) was gradually supplemented with the APS solution and then AA was added drop by drop. At last, the solid, flexible gels that were produced when the gelling mixture was heated were broken and taken out of the test tubes. The gels were cut into 8 mm discs for further usage after being fully dried.

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Table : The Hydrogels' chemical composition concentrations and expressed as a percentage of the formulation

| Designing | XG % | AA % | MBA % | Eu-S100 % | APS % |
|---|---|---|---|---|---|
| F1 | - | 16.6 | 0.33 | 0.66 | 0.2 |
| F2 | 0.66 | 16.6 | 0.33 | - | 0.2 |
| F3 | 0.33 | 16.6 | 0.33 | 0.33 | 0.2 |

Table 2: Formulation scheme of Ciprofloxacin by using Eudragit S100 as polymer

| S. No | Drug to polymer ratio | Drug (CPX) | Polymer (Eu) | Polymer (X G) | Polymer (A A) | Polymer (MBA) | Polymer (APS) |
|---|---|---|---|---|---|---|---|
| F1 | 1:1 | 250mg | 250mg | 250mg | 250mg | 250mg | 250mg |
| F2 | 1:3 | 250mg | 500mg | 500mg | 500mg | 500mg | 500mg |
| F3 | 1:4 | 250mg | 750mg | 750mg | 750mg | 750mg | 750mg |

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### Hydrogels pH-responsively preparation

According to research findings published in their study, hydrogels created using the free-radical polymerization technique (Mahmood *et al.,* 2019). The gel composition is listed in Table 2. Eu-S100 and XG dissolved in a pH-neutral aqueous medium for the thirty minutes at temperature of room with assistance of magnetic stirrer. They were dissolved alone or in combination. The reaction mixture's pH was brought down to a basic level. The APS (Initiator) dissolved in the separate beaker at room temperature. MBA (cross-linking) was dissolved in distilled water in third beaker. The APS solution was added drop-wise in the dispersion (XG/Eu-S100/or both) after it had been slowly stirred continuously for 30 minutes at room temperature of AA. Finally, a slow adding of the cross linking liquid was prepared. The glass test tube then filled with the finished mixture. The test tube containing the gelling mixture subjected to thermal treatment in a hot air oven at 45°C for two hours, 50°C for four hours, and 55°C for eight hours. Flexible gels that were produced after the gelling mixture heat-treated were broken out of the test tubes. After fully drying at 37°C, the gels were sliced into 8 mm-diameter discs for later usage.

### Characterizing the physicochemical properties of ciprofloxacin

In vitro characterization was performed on the hydrogels compositions. Drug release kinetics were investigated by dissolving experiments, drug-hydrogels chemical interaction was examined by FTIR analysis, and morphological study was conducted using electron microscopy.

### Hydrogels' capacity to swell

The analysis's main goal was to look into hydrogels matrices' sorption capacity in detail in relation to swelling. This study is relevant because it needs to be assessed whether hydrogels dressings can be used to effectively absorb medical fluids. Hydrogels discs that

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had been previously manufactured and dried served as the basis for the analysis. First, the precise weight of each sample was determined, and it was then added to a range of incubation solutions, including Ringer's solution, and pure water. The sample has to be incubated in the aforementioned liquids for twenty-four, and seventy-two hours. The extra liquid was drained from the container after each interval of time. Disc surfaces and subsequently a precision electrical balance was used to quantify the discs' weight. Every step of the study was performed three times to reduce errors and provide repeatable results. Ultimately, an average of the swelling coefficient readings from the several tests was used to determine an indicative value for the hydrogels matrices' sorption capacity. Given equation used to compute the percentage swelling. (Cassano, et al. 2024)

$$Q = \frac{W - W_0}{W_0} \times 100$$

$W$= Weight of the swollen hydrogels-discs, $W^0$= Weight of the dried hydrogels-disc

$$\alpha = mt - m0m0$$

where: α = g/g (the swelling ratio);

mt = g (mass of swelled sample after time "t");

m0 = g (mass of dry sample).

## Ciprofloxacin-loading of hydrogels

By means of the swelling-diffusion, the ciprofloxacin was loaded to the hydrogels. Within a 48 hours half the dried hydrogels discs were inserted into a sealed vessel that contained a 30 ml mix of ciprofloxacin of a particular level. The efficacy to determine the loading of CPX capacity was calculated via determining the quantity of drug-solution having a known concentration, which was challenged within a hydrogels disc (Dong *et al.*, 2016).

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### FT-IR Separation

FT-IR was very useful analytical technique in establishing likely chemical interaction in the medicine and the designed components. In the current investigation, the interaction of ciprofloxacin and hydrogels, on a chemical level was assessed through the assessment of FT-IR evaluation (Akhtar, *et al.*, 2015).

### Differential Scanning Calorimetry (DSC).

The fusion heat of polymer hydrogels was carried by DSC (PerkinElmer DSC 4000) analysis (Ullah, *et al.,* 2019).

### Swelling Study

At body temperature, the produced hydrogel's swelling was examined at distinct pH values: 1.6 and 7.0. As a result, the appropriate buffer solutions were submerged in dried hydrogels samples that were precisely weighed. The samples were taken out and blotted by placing filter paper, then weighed once more after certain intervals of time. Until the hydrogels reached an equilibrium weight, this process was carried out (Ijaz, *et al.,* 2019). The following formula was used to calculate the hydrogel's swelling:

$$(q) = K^2 / K^1$$

q shows the dynamic swelling, $K^1$ represents the initial weight of dried disc of the hydrogels before swelling, whereas $K^2$ reveals the final weight after swelling at time t.

### Scanning Electron Microscopy or SEM

SEM was used to inspect the surface morphology and porosity of the hydrogels texture for various formulations.

### Drug release studies conducted in vitro

The in-vitro release of ciprofloxacins hydrogels were determined via dispersion of the same in 900 milliliters of dissolution fluid in the USP Apparatus-II. A dissolving media of

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pH 1.6 and pH 7.0 were used. In the first part, the standard curve was created separately using two dissolving media with the known concentrations of ciprofloxacin. A sample every 1 hour, between 1 hour and 10 hours was taken.

### Characterization of the in vitro drug-release rate

Kinetic models of drug release, Model of Zero order, First order order model, Higuchi model and Korsmeyer-Peppas model.

The mechanical properties of the hydrogels were ascertained through the application of strength analysis. The tensile strength and elongation of the materials under test were ascertained by the analysis (Khanum *et al.*, 2018; Ranjha *et al.*, 2011).

## Results and discussions

### Hydrogels desiging

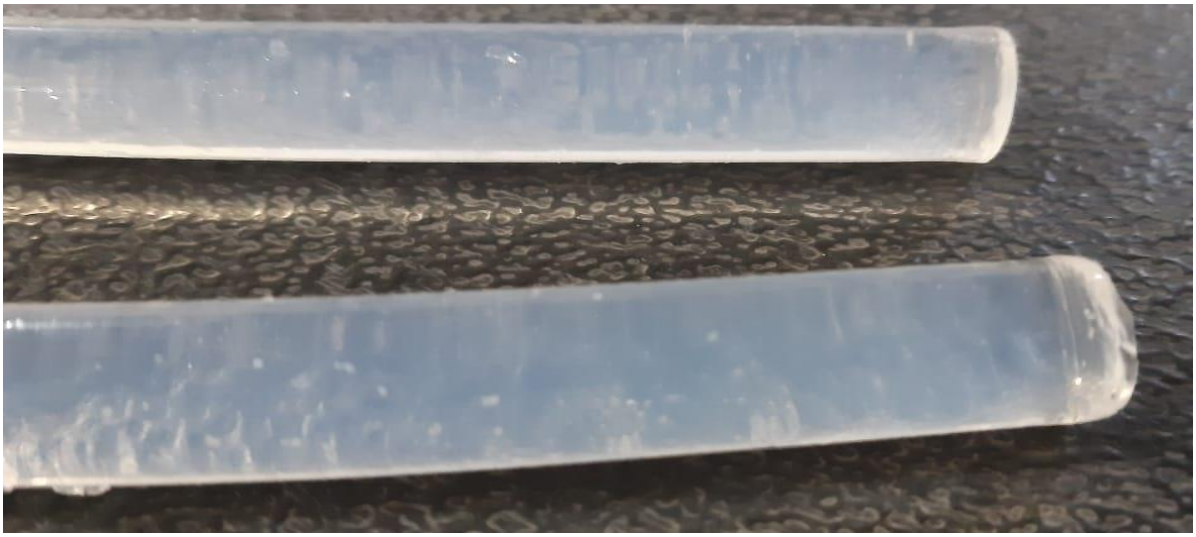

Figure 1: Hydrogels compositions following thermal polymerization

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Figure 2: Hydrogels composition following total drying

### Ability to swell

For every formulation, the hydrogels' swelling percentage (also known as the swellability parameter) were computed. Table 3 lists the hydrogels formulations' % swelling values. Every formulation showed pH-dependent swellability, meaning that swelling rose at a pH of 7.0 and decreased at a pH of 1.6. The formulation F3 was found to have a high magnitude. Additionally, at pH 7.0, F3 showed 3.5 four times as much edema as formulation F1 and four times as much as formulation F2.

Table 3: The percentage-swelling of gels after 24 hours of incubation at 37°C in simulated gastric and duodenal media (n=6).

| Designing | Hydrogel swelling in dissolving media | |
|---|---|---|
| | At pH of 1.6 | At pH of 7.0 |

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| | | |
|---|---|---|
| F1 | 154±27 | 220.35±17 |
| F2 | 166.90±22 | 252.53±19 |
| F3 | 72.72±02 | 882.54±60 |

The mean ± standard error is used to present the results.

## FTIR Analysis

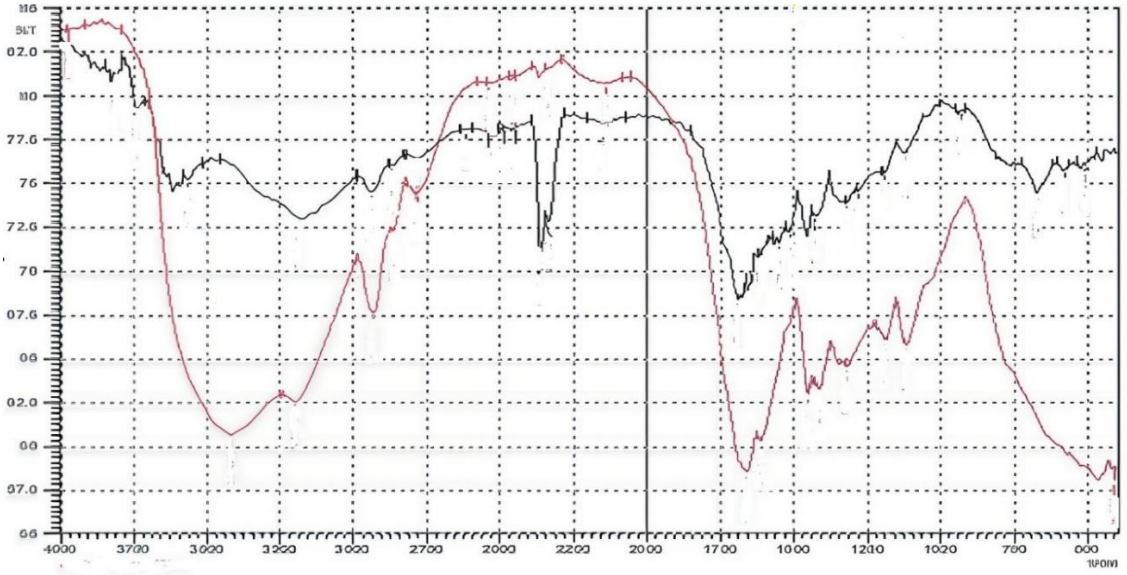

Figure 3: Analysis of FTIR

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Differential Scanning Colerimetry

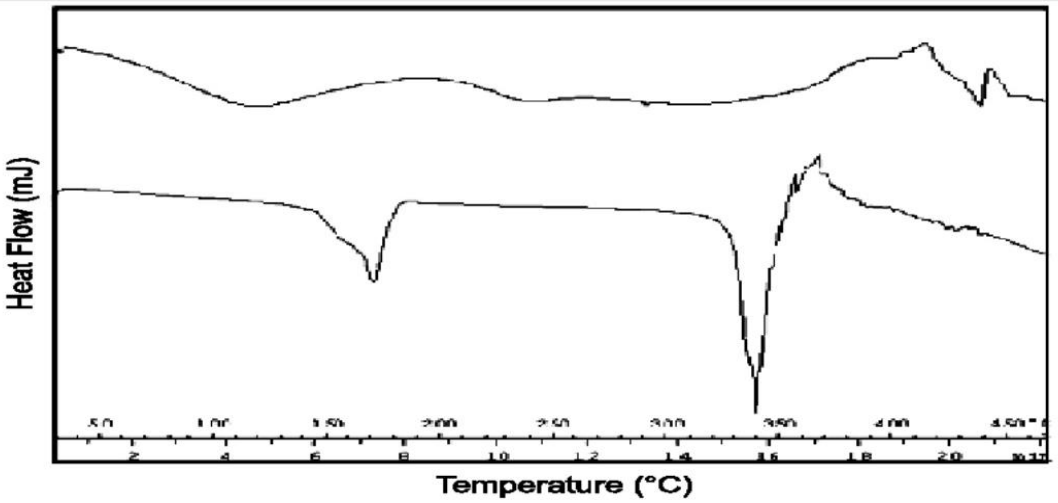


Figure : DCS analysis

Electronmicroscopy

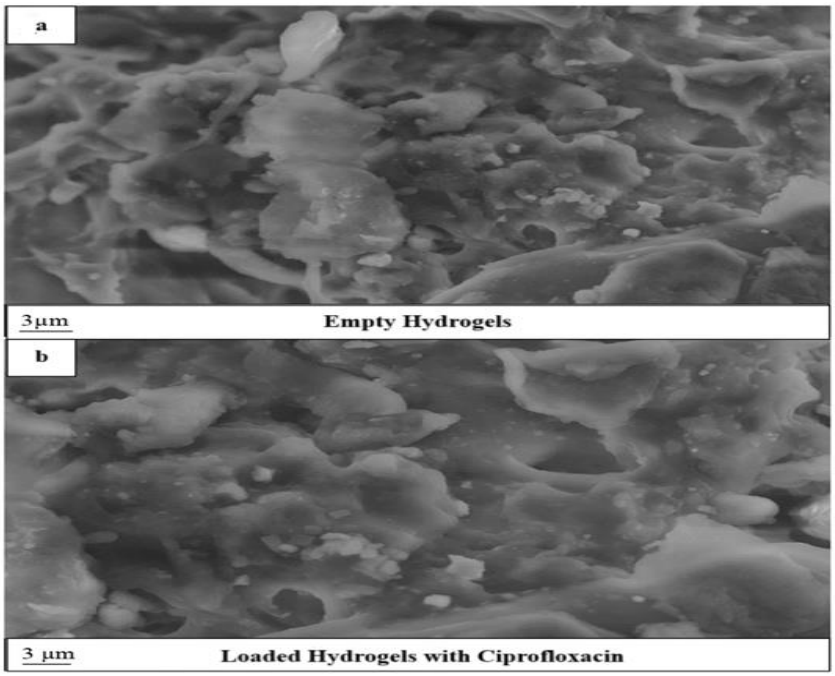

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Figure 5: Electron microscopy of empty hydrogels (XG-EU-AA hydrogels and (b) Ciprofloxacin-loaded hydrogels.

Kinetics for drug release

Table 4: Concentration and their peaks in absorbance at pH 1.6

| Serial No. | Concentration | Absorbance |
|---|---|---|
| 1 | 0.25 | 0.09915 |
| 2 | 0.5 | 0.1238 |
| 3 | 0.75 | 0.14845 |
| 4 | 1 | 0.1731 |
| 5 | 1.25 | 0.19775 |
| 6 | 1.5 | 0.2224 |
| 7 | 1.75 | 0.24705 |
| 8 | 2 | 0.2717 |
| 9 | 2.25 | 0.29635 |

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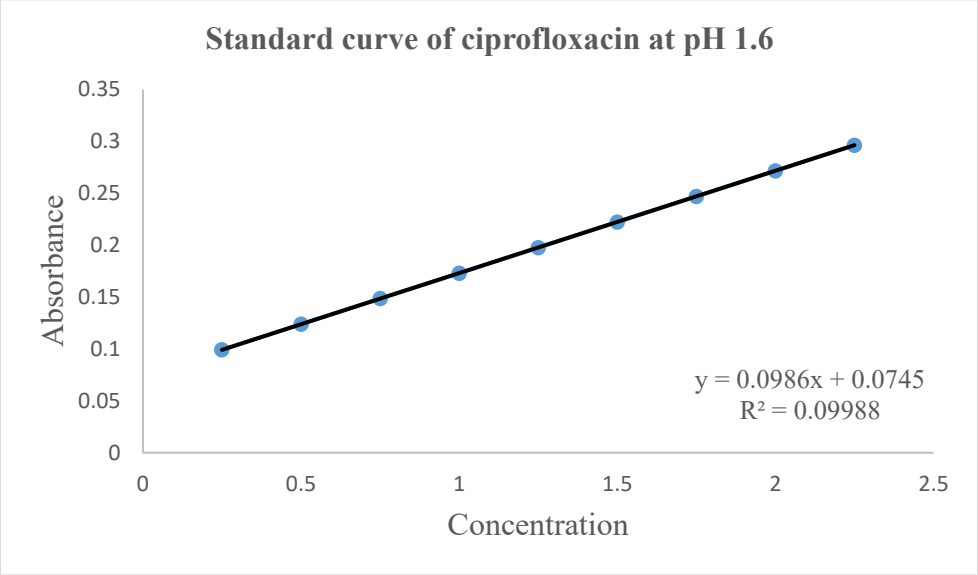


Figure 6: Standard curve of ciprofloxacin at pH 1.6

Table 5: Concentration of ciprofloxacin at absorbance at pH 7.0

| Serial no. | Concentration | Absorbance |
|---|---|---|
| 1 | 0.25 | 0.094625 |
| 2 | 0.5 | 0.11895 |
| 3 | 0.75 | 0.143275 |
| 4 | 1 | 0.1676 |
| 5 | 1.25 | 0.191925 |
| 6 | 1.5 | 0.21625 |
| 7 | 1.75 | 0.240575 |
| 8 | 2 | 0.2649 |

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| | | |
|---|---|---|
| 9 | 2.25 | 0.289225 |

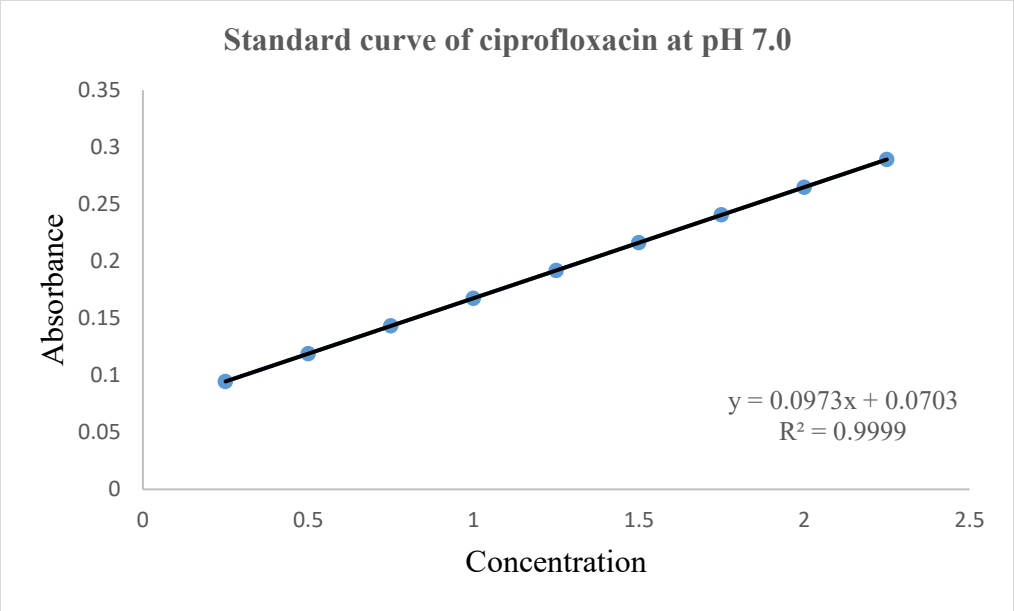


Figure 7. Standard curve of ciprofloxacin at pH 7.0

Table 6. Dissolution of ciprofloxacin at 1.6 pH

| Serial no. | Time (hr) | Release rate (F1) | Release rate (F2) | Release rate (F3) |
|---|---|---|---|---|
| 1 | 05 min | 4.55 | 7.75 | 12.69 |
| 2 | 30 min | 9.115 | 12.125 | 17.645 |
| 3 | 01 hr | 10.605 | 15.135 | 21.105 |
| 4 | 03 hr | 13.715 | 18.775 | 23.925 |
| 5 | 06 hr | 18.46 | 23.245 | 28.995 |
| 6 | 09 hr | 21.925 | 28.175 | 32.275 |

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| | | | | |
|---|---|---|---|---|
| 7 | 15 hr | 31.56 | 38.055 | 41.505 |
| 8 | 18 hr | 39.56 | 43.075 | 45.58 |
| 9 | 24 hr | 43.65 | 45.25 | 49.325 |

Table 7: Percentage drug release at pH 1.6

| Serial number | % Drug release (F1) | % Drug release (F2) | % Drug release (F3) |
|---|---|---|---|
| 1 | 1.82 | 3.1 | 5.076 |
| 2 | 3.646 | 4.85 | 7.058 |
| 3 | 4.242 | 6.054 | 8.442 |
| 4 | 5.486 | 7.51 | 9.57 |
| 5 | 7.384 | 9.298 | 11.598 |
| 6 | 8.77 | 11.27 | 12.91 |
| 7 | 12.624 | 15.222 | 16.602 |
| 8 | 15.824 | 17.23 | 18.232 |
| 9 | 17.46 | 18.1 | 19.73 |

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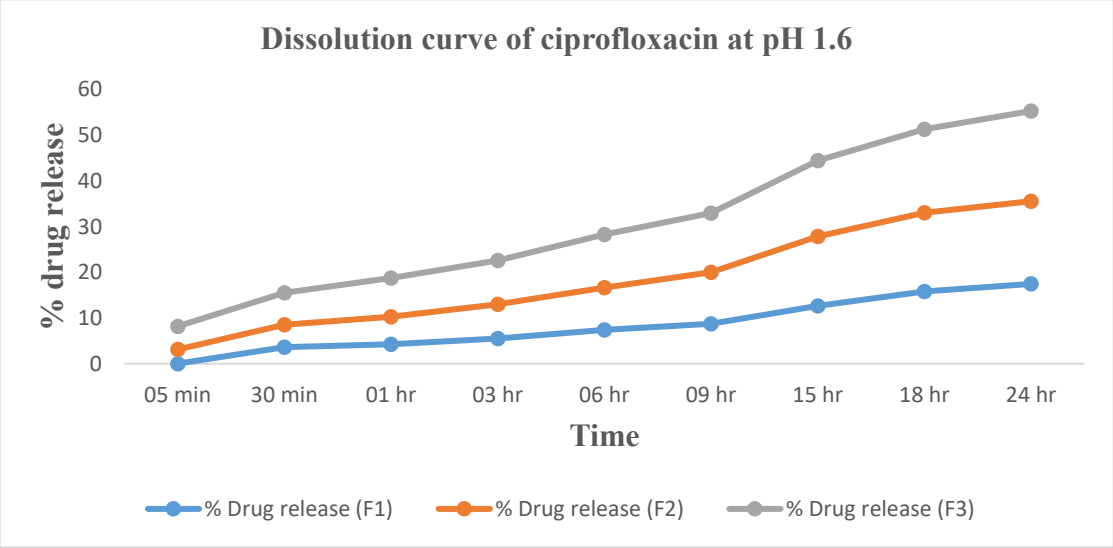


Figure 8: Dissolution curve of ciprofloxacin at pH 1.6

Table 8: Dissolution of ciprofloxacin at pH 7.0

| Serial number | Time hours (hr) | Release rate (F1) | Release rate (F2) | Release rate (F3) |
|---|---|---|---|---|
| 1 | 5 min | 9.1 | 15.5 | 25.38 |
| 2 | 30 | 18.23 | 24.25 | 35.29 |
| 3 | 1 hr | 21.21 | 30.27 | 42.21 |
| 4 | 3 hr | 27.43 | 37.55 | 47.85 |
| 5 | 6hr | 36.92 | 46.49 | 57.99 |
| 6 | 9hr | 43.85 | 56.35 | 64.55 |
| 7 | 15hr | 63.12 | 76.11 | 83.10 |
| 8 | 18hr | 79.12 | 86.15 | 91.16 |
| 9 | 24hr | 87.3 | 90.5 | 98.65 |

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Table 9. Percentage drug release at pH 7.0

| Serial number | Time hours (hr) | % Drug release (F1) | % Drug release (F2) | % Drug release (F3) |
|---|---|---|---|---|
| 1 | 5 min | 3.64 | 6.2 | 10.152 |
| 2 | 30 | 7.292 | 9.7 | 14.116 |
| 3 | 1 hr | 8.484 | 12.108 | 16.884 |
| 4 | 3 hr | 10.972 | 15.02 | 19.14 |
| 5 | 6hr | 14.768 | 18.596 | 23.196 |
| 6 | 9hr | 17.54 | 22.54 | 25.82 |
| 7 | 15hr | 25.248 | 30.444 | 33.24 |
| 8 | 18hr | 31.648 | 34.46 | 36.464 |
| 9 | 24hr | 34.92 | 36.2 | 39.46 |

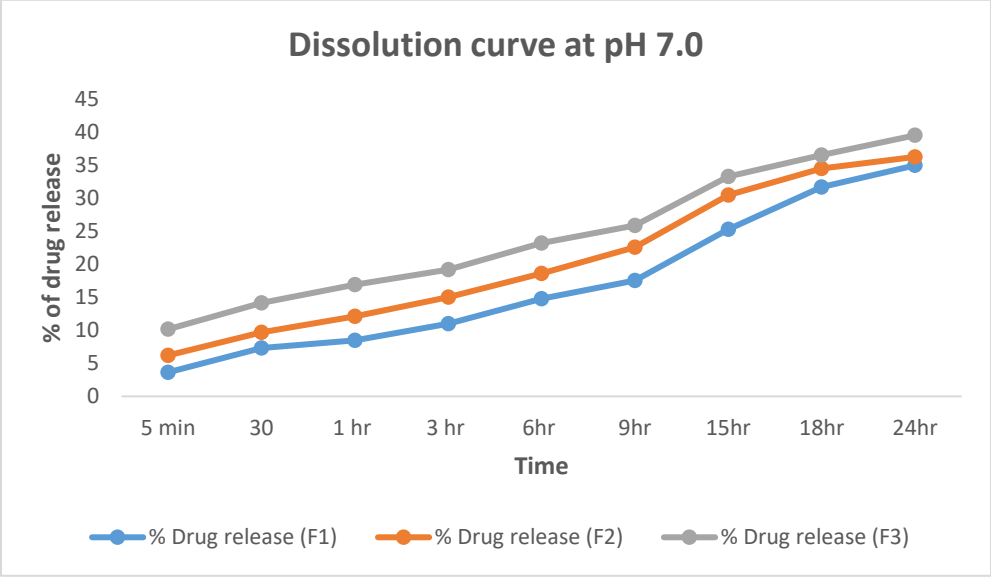


Figure 9: Dissolution curve at pH 7.0

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Table 10: Rate release at 1.6 pH

| Serial number | Time hours (hr) | Release rate (F1) | Release rate (F2) | Release rate (F3) |
|---|---|---|---|---|
| 1 | 5 min | 9.1 | 15.5 | 25.38 |
| 2 | 30 | 18.23 | 24.25 | 35.29 |
| 3 | 1 hr | 21.21 | 30.27 | 42.21 |
| 4 | 3 hr | 27.43 | 37.55 | 47.85 |
| 5 | 6hr | 36.92 | 46.49 | 57.99 |
| 6 | 9hr | 43.85 | 56.35 | 64.55 |
| 7 | 15hr | 63.12 | 76.11 | 83.10 |
| 8 | 18hr | 79.12 | 86.15 | 91.16 |

Table 11: Rate release at pH 7.0

| Serial number | Time hours (hr) | % Drug release (F1) | % Drug release (F2) | % Drug release (F3) |
|---|---|---|---|---|
| 1 | 5 min | 3.64 | 6.2 | 10.152 |

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| | | | | |
|---|---|---|---|---|
| 2 | 30 | 7.292 | 9.7 | 14.116 |
| 3 | 1 hr | 8.484 | 12.108 | 16.884 |
| 4 | 3 hr | 10.972 | 15.02 | 19.14 |
| 5 | 6hr | 14.768 | 18.596 | 23.196 |
| 6 | 9hr | 17.54 | 22.54 | 25.82 |
| 7 | 15hr | 25.248 | 30.444 | 33.24 |
| 8 | 18hr | 31.648 | 34.46 | 36.464 |
| 9 | 24hr | 34.92 | 36.2 | 39.46 |

Table 12: Drug release with zero order Model

| Parameters | At pH of 1.6 | | | At pH of 7.0 | | |
|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | F1 | F2 | F3 |
| $K^0$ | 1.59 | 1.56 | 1.46 | 3.184 | 3.107 | 2.1002 |
| AIC | 15.07 | 21.10 | 21.07 | 27.64 | 34.45 | 33.64 |
| $R^2$ | 0.99 | 0.96 | 0.954 | 0.190 | 0.1443 | 0.144 |
| MSC | 3.81 | 3.00 | 2.15 | 14.13 | 14.74 | 15.33 |

Table 13: First order drug release model

| Parameters | At pH 1.6 | | | At pH 7.0 | | |
|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | F1 | F2 | F3 |
| $K^1$ | 0.0215 | 0.0220 | 0.0219 | 0.049 | 0.073 | 0.049 |
| AIC | -65.44 | -59.47 | -60.81 | -18.93 | -22.14 | -28.34 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| $R^2$ | 0.981 | 0.985 | 0.984 | 0.9400 | 0.8311 | 0.9411 |
| MSC | 4.91 | 3.01 | 3.16 | 5.49 | 5.48 | 6.21 |

Table 14: Higuchi drug model

| Parameters | At pH of 1.6 | | | At pH of 7.0 | | |
|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | F1 | F2 | F3 |
| $K^H$ | 5.12 | 5.14 | 4.94 | 18.45 | 19.10 | 21.57 |
| N | 0.31 | 0.37 | 2.54 | 0.46 | 0.40 | 0.35 |
| AIC | 4.5 | 2.8 | 3.0 | 55.12 | 53.58 | 51.87 |
| $R^2$ | 0.971 | 0.992 | 0.990 | 0.994 | 0.996 | 0.997 |
| MSC | 3.4 | 3.7 | 3.6 | 16.32 | 17.01 | 19.16 |

Table 15: Model of Korsmeyer-Peppas medication release

| Parameters | At pH 1.6 | | | At pH 7.0 | | |
|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | F1 | F2 | F3 |
| $K^H$ | 10.91 | 15.28 | 21.12 | 21.911 | 30.544 | 41.113 |
| $R^2$ | 0.973 | 0.982 | 0.971 | 0.1642 | 0.1713 | 0.1426 |
| AIC | -32.31 | -38.01 | -40.41 | -47.32 | -53.02 | -55.70 |
| MSC | 3.20 | 3.42 | 3.15 | 2.12 | 3.33 | 3.72 |

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## Discussion

For the oral administration of ciprofloxacin medication, extended-release, pH-responsive hydrogels were developed in the current study. To modify the relative concentrations of the monomer, cross-linkers, gel-initiator, XG, and Eu-S100 required for gel formation, preliminary error-trial studies were started. All formulas designated F1, F2, and F3 produced viscous semi-transparent dispersions upon early component mixing. Designing F1 somewhat extra translucent than the formulations F2 and F3. As compared to F1, the F2 and F3 were marginally more viscid. In one hour following thermal treatment, the gelling process began. Highly elastic gels with a rubbery consistency were produced after thermal treatment. When a mechanical force was applied, none of the three gels broke (Fig.1). Following drying, the the transparency was found to increase (Fig. 2).

Free-radical polymerization was the method used in this work to create the hydrogels. The initiator molecule is ionized in the aqueous medium, producing sulphate and hydroxyl ions. The gelling mixture's polymerization is started by these ions. When XG or Eu dispersion is added, the ions or free radicals interact with the XG or Eu backbone to form binding sites. To increase the length of the polymeric chain, the activated Eu or XG act as a donor for a monomer such as AA. The last stage of cross-linking creates cross-linking and increases the stiffness and asset of the hydrogels. (Gils *et al.*, 2009). The polyelectrolyte complexation (PC) is the most common event involved in the creation of Eu-XG-AA (F3) hydrogels. In PC, electrostatic interaction between two oppositely charged chemical entities forms complexes with considerable mechanical strength. Both polymer-polymer and polymer-drug complexes are possible. Researchers have reported a particular kind of complex between XG and Eu for regulated medication delivery (Deb *et al.*, 2024). It has been observed that the initiator Both Eu-S100 and XG molecules can

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develop charged groups thanks to the APS used in this investigation. In the F3 formulation, such charged groups may have led to the development of a complex between Eu-S100-XG. Future research is required to clarify the precise molecular nature of this interaction (Gils *et al.*, 2009).

The current investigation found that the hydrogels formulations' reduced swellability at the pH of acid and their improved swellability at the pH of 7.0 were in line (Trombino *et al.*, 2019). The formation of a repulsive force between the gels' polymeric chains may have contributed to the high swelling ratio of hydrogels at higher pH values. This force finally forced the chains apart, allowing an increasing number of water molecules to build up in the gel matrix. One reason for the repulsive interactions between the separation of charged groups in polymeric chains was brought on by a higher pH. (Yeole et al., 2006).

The experiment's findings indicate that the gel designing utilized to deliver only a small amount of a drug's load into the stomach and most of it into the intestine. This kind of formulation might be a useful drug delivery method for medications whose primary absorption site is the duodenum. The high water-retention capacity of XG (Malik *et al.*, 2020) have contributed to the increased swellability of F3, which was further increased upon inducing Eu-XG complexation. These results imply that F3 embodies the desirable qualities of medications whose primary site of absorption is the duodenum.

The DSC curves for pure ciprofloxacin (bottom) and polymers (top) are displayed in Figure 4 The pure drug's (ciprofloxacin) thermal behavior displays endotherms between 168.88°C and 335.00°C, which links the melting and loss of the crystallization of water. Thermal behavior reveals a melting endotherm of the medication at 335°C and a fractional loss of water between 100°C and 140°C. The optimum complex's beginning (endothermic-exothermic inversion) and progressive breakdown, however, are shown by a tiny, gradual

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exotherm on the given curves at 428°C. Here is little breakdown of drug in hydrogels which shows this is thermally stable if placed at higher temperature.

Only F3 was subjected to electron microscopy because drug release tests showed promising results with this formulation. The formulation of empty and loaded hydrogels as seen in the SEM picture figure 5 F3 are represented in the hydrogels formulation's surface shape offers incredibly helpful indicators for predicting the fundamental mechanism of drug release. According to (Gholamali *et al.*, 2020), the properties of hydrogels also control the kinetics of drug release.

Table 4, 5 and figures 6 and 7 shows Standard curves with known concentrations of CPX showed $R^2$ values of 0.9998 for the pH of 1.6 and 0.9999 at the pH of 7.0. The significant linearity in the CPX concentrations and the UV-visible absorbance values at 232nm is evident from these findings. Figures. 8–9 and tables 6 to 11 show a representation of the profile of medication release from CPX filled hydrogels designed at the pH of 1.6 and the 7.0. The pH of the dissolving environment influenced the hydrogels' swellability was crucial to the drug release. At pH 7.0, hydrogels exhibited strong swellability and maximal drug release; at pH 1.6, they displayed low swellability and poor drug release. Since the supplied formulation released 50% more medication at the pH of 7.0 as compare to the medium at the pH of 1.6, the case of F3 showed the highest pH influence on the percentage of difference at the end of the 24-hour release. At pH of 1.6, total percentage of CPX released from F3 was 19.76 % and at the pH of 7.0, it was 39.46%. In both dissolution media, F3 produced less variation in the CPX release than the other two formulations. Using drug release kinetic models and Microsoft Excel, the kinetics of drug release were computed. Tables 12–15 present the drug release kinetics results. None of the hydrogels formulations adhered to the Zero-order, Higuchi models or First-order in

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the pH 1.6 dissolution media, according to the CPX release kinetics. F2 adhered strictly to the Korsmeyer-Peppas Model. Regarding the release of CPX in a pH 7.0 medium, the F2 formulation closely adhered to the First-order and Korsmeyer-Peppas Models. The composition of F3 hydrogels adhered to the Korsmeyer-Peppas and Higuchi models. (Ebrahimi, *et al.*, 2018)

Following the standard procedure described in official compendia, CPX release profiling from hydrogels formulations was carried out for a duration of 1 to 24 hours. All three of the formulations utilized in this study showed pH-dependent drug release, which means that the drug released less at a pH of 1.6 and more at a pH of 7.0. The pH-dependent drug-release response of F3 was greater than that of F1 and F2. The hydrogels' acrylic acid carboxylic acid, which has an acidic pH, may be the reason for the reduced CPX release from low pH hydrogel formulations. It stays unionized and creates more cross-links by the Hydrogen bond establishment, leads to inadequate swelling and, eventually, inadequate release of CPX. The ionization of carboxylic acid groups in polymeric chains occurs at pH 7.0. gave acrylic acid a negative charge and caused repulsion between the chains, which in turn caused swelling and release of drug at higher pH values, according to (Bajpai *et al.,* 2019). The drug release patterns of the study indicate that XG-Co-AA hydrogels release paracetamol in a pH-dependent manner, while Eu-Co-AA hydrogels release losartan potassium in a pH-dependent manner (Masood, N., 2022). The behavior of CPX release from different formulations confirms that hydrogels designing, especially the F3, are appropriate for intestinal administration of CPX model medicines with good release profile.

F3 offered kinetics of sustained release. As previously described by the researchers, the sustained-release pattern of CPX from hydrogels may have been significantly influenced

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by interface of CPX with the hydrogels medium by their functional groups (Vilches, *et al.*, R. H. (2002). According to kinetic tests, Fickian release at pH 1.6 was followed by CPX releases from the F2 (Xathan gum) formulation and first-order kinetics at pH 7.0 According to the Higuchi model, CPX was released from the formulation F3 XG-Eu-AA via a combination of diffusion and erosion. (Abou-Okeil, *et al.*, 2024).

## Conclusion and Recommendations

For the site specific administration of a classical medication, CPX, both natural and synthetic polymers were effectively used to construct pH-responsive hydrogels. By combining chemical and thermal cross-linking, hydrogels were created. The hydrogels formulation and the CPX did not interact chemically, according to FT-IR measurements. The gel matrix's porous features with interconnected tunnels to promote water diffusion were confirmed by SEM investigation. Poor swellability and drug release were seen in the Eu-S100-XG-AA hydrogels formulation at acidic pH values, while excellent swellability and a comparatively large pH 7.0 at total amount of drug release demonstrated the formulation's pH-responsive drug release capacity. There was very little fluctuation in the steady-state medication release. For prolonged and definite delivery for organ of medications which primary organ of absorption is in the duodenum, EuS100-XG-AA hydrogels has been discovered for viable drug delivery technology. Additionally, the current study provided evidence for the concept combining synthetic and natural polymers can result in a pH-responsive medication delivery system release control that works incredibly well for a variety of hydrophilic and lipophilic medications. To assess the formulation's cytotoxicity and the loaded antibacterial drug's pharmacokinetic characteristics, more research is needed.

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## REFERENCES

Drews, J. (2000). Drug discovery: A historical perspective. *Science, 287*(5460), 1960-1964.

Grassi, T., Bovino, S., Schleicher, D. R. G., Prieto, J., Seifried, D., Simoncini, E., & Gianturco, F. A. (2014). KROME: A package to embed chemistry in astrophysical simulations. *Monthly Notices of the Royal Astronomical Society, 439*(3), 2386-2419.

Uhrich, K. E., Cannizzaro, S. M., Langer, R. S., & Shakesheff, K. M. (1999). Polymeric systems for controlled drug release. *Chemical Reviews, 99*(11), 3181-3198.

Wadher, K. J., Kakde, R. B., & Umekar, M. J. (2011). Sustained-release metformin tablets using synthetic and natural polymers. *Indian Journal of Pharmaceutical Sciences, 73*(2), 208-214.

Seow, Y. X., Yeo, C. R., Chung, H. L., & Yuk, H. G. (2014). Plant essential oils as active antimicrobial agents. *Critical reviews in food science and nutrition*, *54*(5), 625-644.

Lee, Y., Park, J., Ryu, C., Gang, K. S., Yang, W., Park, Y. K., ... & Hyun, S. (2013). Comparison of biochar properties from biomass residues produced by slow pyrolysis at 500 C. *Bioresource technology*, *148*, 196-201.

Drexler, J. W., & Powell, H. M. (2011). Regulation of electrospun scaffold stiffness via coaxial-core diameter. *Acta Biomaterialia, 7*(3), 1133-1139.

Pishko, M. V., Michael, A. C., & Heller, A. (1991). Amperometric glucose microelectrodes via redox hydrogels. *Analytical Chemistry, 63*(20), 2268-2272.

Tevyashova, A. N., Olsufyeva, E. N., & Preobrazhenskaya, M. N. (2015). Dual-action antibiotics: A promising approach. *Russian Chemical Reviews, 84*(1), 61-85.

Bansal, S., Aggarwal, G., Chandel, P., & Harikumar, S. L. (2013). Design and development of cefdinir niosomes for oral delivery. *Journal of Pharmacy and Bioallied Sciences*, *5*(4), 318-325.

Pakistan Journal of Medical & Cardiological Review
https://pakjmcr.com/index.php/1/about

Online ISSN 3007-2387
Print ISSN 3007-2379



DOI: http://doi.org/10.5281/zenodo.18994907

Felt, O., Buri, P., & Gurny, R. (1998). Chitosan: a unique polysaccharide for drug delivery. *Drug development and industrial pharmacy*, *24*(11), 979-993.

Mahmood, S., Buabeid, M. A., Ullah, K., Murtaza, G., Mannan, A., & Khan, S. A. (2019). Eudragit-based pH-responsive hydrogels for colonic delivery of losartan. *Current Drug Delivery, 16*(6), 548-564.

Cassano, R., Curcio, F., Sole, R., Mellace, S., & Trombino, S. (2024). Gallic acid-based hydrogels for phloretin intestinal release: a promising strategy to reduce oxidative stress in chronic diabetes. *Molecules*, *29*(5), 929.

Dong, D., Li, J., Cui, M., Wang, J., Zhou, Y., Luo, L., ... & Yao, F. (2016). In situ "clickable" zwitterionic starch-based hydrogel for 3D cell encapsulation. *ACS applied materials & interfaces*, *8*(7), 4442-4455.

Akhtar, K., Bakhsh, E. M., & Khan, S. B. (2022). Versatility of hydrogels: From synthetic strategies, classification, and properties to biomedical applications. *Gels, 8*(3), 167.

Ullah, K., Sohail, M., Buabeid, M. A., Murtaza, G., Ullah, A., Rashid, H., ... Khan, S. A. (2019). Pectin-based (LA-co-MAA) semi-IPNs for colonic delivery of oxaliplatin. *International Journal of Pharmaceutics, 569*, 118557.

Ijaz, H., Tulain, U. R., Azam, F., & Qureshi, J. (2019). Thiolated arabinoxylan-g-AA pH-sensitive copolymer fabrication. *Drug Development and Industrial Pharmacy, 45*(5), 754-766.

Khanum, H., Ullah, K., Murtaza, G., & Khan, S. A. (2018). HPMC-g-AMPS hydrogels loaded with loxoprofen sodium: Fabrication and in-vitro characterization. *International Journal of Biological Macromolecules, 120*, 1624-1631.

Pakistan Journal of Medical & Cardiological Review
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Online ISSN 3007-2387
Print ISSN 3007-2379



DOI: http://doi.org/10.5281/zenodo.18994907

Ranjha, N. M., Mudassir, J., & Majeed, S. (2011). PCL/AA hydrogel for controlled drug delivery: Synthesis and characterization. *Bulletin of Materials Science, 34*(7), 1537-1547.

Gils, P. S., Ray, D., Mohanta, G. P., Manavalan, R., & Sahoo, P. K. (2009). Acrylic macroporous super-absorbent hydrogel for drug delivery. *International Journal of Pharmacy and Pharmaceutical Sciences, 1*, 43-54.

Deb, D., Khatun, B., M, B. D., Khan, M. R., Sen Sarma, N., & Sankaranarayanan, K. (2024). Utilizing Silk Sericin as a Biomaterial for Drug Encapsulation in a Hydrogel Matrix with Polycaprolactone: Formulation and Evaluation of Antibacterial Activity. *ACS omega*, *9*(30), 32706-32716.

Trombino, S., Servidio, C., Curcio, F., & Cassano, R. (2019). Strategies for hyaluronic acid-based hydrogel design in drug delivery. *Pharmaceutics*, *11*(8), 407.

Yeole, P. G., Galgatte, U. C., Babla, I. B., & Nakhat, P. D. (2006). Xanthan-gum sustained-release matrix tablets of diclofenac sodium: Design and evaluation. *Indian Journal of Pharmaceutical Sciences*, 186-190.

Malik, N. S., Ahmad, M., Minhas, M. U., Tulain, R., Barkat, K., Khalid, I., & Khalid, Q. (2020). Chitosan/xanthan-gum hydrogels as antiviral-drug carriers. *Frontiers in Chemistry, 8*, 50.

Gholamali, I., & Yadollahi, M. (2021). Bio-nanocomposite polymer hydrogels containing nanoparticles for drug delivery: A review. *Regenerative Engineering and Translational Medicine, 7*, 129-146.

Ebrahimi, R., & Salavaty, M. (2018). Controlled ciprofloxacin delivery from ultrasonic hydrogel. *e-Polymers, 18*(2), 187-195.

Pakistan Journal of Medical & Cardiological Review
https://pakjmcr.com/index.php/1/about

Online ISSN 3007-2387
Print ISSN 3007-2379



DOI: http://doi.org/10.5281/zenodo.18994907

Bajpai, A. K., Vishwakarma, A., & Bajpai, J. (2019). Synthesis and characterization of amoxicillin-loaded PVA-g-PAM hydrogels and swelling-triggered drug release. *Polymer Bulletin, 76*, 3269-3295.

Masood, N. (2022). Xanthan-gum/Eudragit controlled-release hydrogel using metformin: Formulation and characterization. *Pak-Euro Journal of Medical and Life Sciences, 5*(1), 81-92.

Vilches, A. P., Jimenez-Kairuz, A., Alovero, F., Olivera, M. E., Allemandi, D. A., & Manzo, R. H. (2002). Fluoroquinolone release kinetics from carbomer hydrogels. *International Journal of Pharmaceutics, 246*(1-2), 17-24.

Abou-Okeil, A., & Taha, G. M. (2024). Investigation and kinetics … ciprofloxacin hydrochloride. *Polymer Bulletin, 81*(18), 17393-17411.