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RESEARCH ARTICLE

DEVELOPMENT OF ORAL MULTIPARTICULATE TIME CONTROLLED PULSATILE DELIVERY SYSTEM OF ACECLOFENAC BASED ON SWELLABLE HYDROPHILLIC POLYMERS FOR CHRONOTHERAPY OF RHEUMATOID ARTHRITIS

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ABSTRACT

The objective of present investigation is to offer controlled release of aceclofenac in the intestinal zone from a novel multipartculate pulsatile system filled with mixed blend polymer microcapsules to achieve the chronotherapy of rheumatoid arthritis. Seven batches of microbeads with varying concentration of sodium alginate (2-5 %w/v) were prepared by ionotropic-gelation method using $CaCl_2$ as cross-linking agent. The prepared Ca-alginate beads were coated with 5% w/v Eudragit L100 and filled into pulsatile capsule with varying proportion of plugging materials. Drug loaded microbeads were investigated for physicochemical properties and drug release characteristics. The mean particle sizes of drug-loaded microbeads were found to be in the range 596.45±1.04 to 860.10±1.14 micron and %DEE in the range of 65.43-84.5%. FT-IR and DSC studies revealed the absence of drug polymer interactions. The release of aceclofenac from formulations F1 to F7 in buffer media (pH 6.8) at the end of 5h was 65.6, 60.7, 55.7, 41.2, 39.2, 27.17 and 25.4% respectively. Pulsatile system filled with eudragit coated Ca-alginate microbeads (F2) showed better drug content, particle size, surface topography, in-vitro drug release in a controlled manner. Different plugging materials like Sterculia gum, HPMC K4M and Carbopol were used in the design of pulsatile capsule. The pulsatile system remained intact in buffer pH 1.2 for 2 hours due to enteric coat of the system with HPMCP. The enteric coat dissolved when the pH of medium was changed to 7.4. The pulsatile system developed with Sterculia gum as plugging material showed satisfactory lag period when compared to HPMC and Carbopol.

Keywords: *Aceclofenac, Chronotherapy, Eudragit L100, Microbeads, Pulsatile, Sterculia.*

INTRODUCTION

Chronopharmacotherapy for rheumatoid arthritis has been recommended to ensure that the highest blood levels of the drug coincide with peak pain and stiffness. Chronotherapeutics refers to a treatment method in which in-vivo drug availability is timed to match rhythms of disease in order to optimize therapeutic outcomes and minimize side effects. The half-life of anti-inflammatory drug aceclofenac is around 4 hours, protein binding of 99.7% and the usual dose is 100 mg. A pulsatile drug delivery system that can be administered at night (before sleep) but that release drug in early morning would be a promising chronopharmaceutics system. Drug pharmacokinetics too shows circadian variation for various anti-inflammatory drugs which have

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greater absorption in morning as compared to evening, and site-specific absorption from small intestine. Therefore, to develop dosage form for chronopharmacotherapy the desired drug release should be time-specific as well as site-specific also. The site-specific delivery of the drugs to the target sites has the potential to reduce the side effects and improved the pharmacological response [1], [2]. Oral controlled release products are formulated to release active ingredient gradually and predictably over a 12 to 24 hour period. The objective of the present study is to develop dosage form for chronopharmacotherapy in the form of time controlled oral pulsatile delivery system of aceclofenac with selected swellable polymers to offer site-specific as well as controlled release in the intestinal zone after defined lag time. The objective of present investigation is to prepare aceclofenac loaded calcium alginate beads to provide sustained release and minimizing or eliminating drug release in the upper gastro intestinal tract. Calcium alginate microbeads are established to be promising tool for oral sustained/ controlled drug delivery but show several problems, mainly related to the stability, and rapid drug release at higher pH that, in most cases, is too fast due to increase porosity. To overcome such inconveniences, CA microbeads coated with eudragit L100 as drug release modifiers to improve stability and prolong the drug release [1,3]. Thus, the objective of present investigation is to offer controlled release of aceclofenac in the intestinal zone from a novel multipartculate pulsatile system filled with mixed blend polymer microcapsules to achieve the chronotherapy of rheumatoid arthritis.

MATERIAL AND METHODS

Aceclofenac sample was purchased from CDH, Kolkata, India. The natural polymers such as sodium alginate, guar gum, carbopol, HPMC K4M were purchased from Krystall Colloids, Gujrat, India. Eudragit L100 (Rohm Pharma, GmbH, Darmstadt, Germany.) supplied by CDH Kolkata. Hydrated Calcium Chloride is obtained from CDH, Kolkata, India. All other chemicals used were of analytical grade.

Solubility of Aceclofenac Sodium in Calcium Chloride Solution

The solubility of drug in a calcium chloride (1%w/v) was determined by adding excess of drug into the medium containing vials and shaking at constant temperature 37^0C in a water bath for 12h. The sample were filtered diluted with distilled water and assayed spectrophotometrically at 274 nm [1, 4].

Saturation solubility determination

Excess quantity of aceclofenac sodium was added to each 25ml volumetric flask containing measured amount of distilled water, phosphate buffer pH 6.8, and phosphate buffer pH 7.4, water to get a saturated solution and agitated continuously at room temperature at 8 hour on a shaker [5-7]. An aliquot was filtered and the filtrate was suitably diluted and analysed for drug content on a UV Spectrophotometer (Schimadzu, Japan, UV 1800 240V).

FT-IR study:

Drug polymer interactions were studied by FT-IR spectroscopy. One to two mg of aceclofenac sodium alone, mixture of drug and polymer were weighed and mixed properly with potassium bromide uniformly. A small quantity of the powder was compressed into a thin semitransparent pellet by applying pressure of 10 kg/cm^2. The IR- spectrum of the pellet from 450-4000 cm^{-1} was recorded taking air as the reference and compared to study any interference. Drug alone and 1:1 binary mixtures of drug with individual polymers were prepared and examined for presence of interactions [7, 8].

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Differential scanning calorimetry (DSC) study:

Differential scanning calorimetry (DSC) of the bulk drug aceclofenac was performed using Perkin Elmer instrument (Perkin Elmer, Jade, USA) for measurement of the heat loss or gain resulting from physical or chemical changes within a sample as a function of temperature. About 6-7 mg of the individual components or drug-excipients combinations were weighed & placed on the 50 µL of aluminium pan in a hermetically sealed condition. The measurement was performed in a nitrogen atmosphere (20 mL/minute) between DSC temperatures at 40ºC to 300ºC at a heating rate of 10 ºC/minute. An empty sealed pan was used as reference. The heat flow as a function of temperature was measured for the drug and drug -polymer mixture [5, 8].

Preparation of sodium alginate microbeads of aceclofenac :

Sodium alginate microbeads were prepared by ionotropic-gelation method. Briefly, sodium alginate (2 to 4% w/v) was dissolved in deionized water and aceclofenac was homogeneously dispersed in it **(Table 1).** Air bubbles were removed from the dispersion by sonication on a bath sonicator. The alginate-drug mixture was then added dropwise (1 ml min^{-1} from 5 cm distance) to a gently agitated cross-linking solution (5% calcium chloride aqueous solution (pH 5.5) through a blunt end needle (25 G) at room temperature (RT). The beads formed were allowed to stand in the solution for specified time interval with gentle agitation. The beads were then separated, washed with distilled water, and subsequently dried at room temperature for 24 hr and stored in desiccators. The prepared seven batches of microbeads with varying concentration of sodium alginate (2-4 %w/v) were coated with 5% w/v Eudragit L100 solution by simple dip coating procedure before incorporated in to the final designed pulsatile capsule [5-9].

Physical evaluation of the prepared microsphere

Size Analysis of Microspheres

Different sizes in a batch are separated by sieving using a range of standard sieves 20/40, 40/60 and 60/80 and the amount retained on different sieves were weighed. Studies were carried out in triplicate. The average sizes of the microspheres were calculated by using the equation [5-7]:

$$D_{ave} = \frac{\Sigma X_i f_i}{f_i}$$

Where,

X_i is the mean size of the range

f_i is the percent material retained on the smaller sieve in the size range.

% yield determination

The percentage yield of the microbeads was calculated by using the following formula [6, 7]:

% yield = Microbeads practically found /Theoretical weight of drug and excipients × 100

Drug entrapment efficiency

Crushed microbeads (100 mg) were taken in a 100 ml volumetric flask and volume was made up to mark with phosphate buffer of pH 6.8. The flask was shaken for 4 hrs using water bath shaker. Then the solution was filtered and from the filtrate appropriate dilutions were made and absorbance was measured at 274 nm by using UV-Visible spectrophotometer. The encapsulation efficiency was calculated using the formula [6,7]:

D. E. E = Actual drug content / Theoretical wt. of drug and excipient X 100.

In-vitro drug release studies of aceclofenac loaded microbeads

In vitro dissolution profile of each formulation was determined by employing USP type-I rotating basket method (900 ml of pH 6.8-phosphate buffer, 100 rpm, 37±0.5 ^{0}C). Eudragit coated alginate microspheres equivalent to 100 mg of drug was loaded into the basket of the

dissolution apparatus and continued the dissolution process. 5 ml of the sample was withdrawn from the dissolution media at suitable time intervals and the same amount was replaced with fresh buffer. The amount of drug present in the filtrate was determined at wavelength of 274 nm by using UV-visible spectrophotometer [6-7].

Preparation of cross-linked gelatin capsules:

Initially hard gelatin capsule bodies were treated with formaldehyde solution to render them insoluble in gastro intestinal fluids while the caps remained untreated. 25 ml of 15% (v/v) formaldehyde was taken into desiccator and a pinch of potassium permanganate was added to it to generate formalin vapors. About 100 numbers of empty bodies of hard gelatin capsule (# 00) were placed over wire mesh and then exposed to formaldehyde vapors. The desiccator was tightly closed, exposed for 12 hrs and dried at 50°C for 30 min to ensure complete reaction between gelatin and formaldehyde vapors. The bodies were then dried at room temperature to facilitate removal of residual formaldehyde. These bodies were joined with untreated caps and stored in a polythene bag [8-10].

Fabrication of capsular type pulsatile system containing aceclofenac loaded coated alginate microbeads

Eudragit coated alginate beads (F2) equivalent to 100 mg of drug were accurately weighed and filled into the treated bodies by hand filling. The capsules containing the microcapsules were then plugged with different amounts (20, 30 and 40 mg) of various sweallable polymers, i.e., guar gum, HPMC, K4M, carbopol etc. The joint of the capsule body and cap was sealed with a small amount of the 5% ethyl cellulose ethanolic solution. The sealed capsules were completely coated with 5% w/v HPMCP solution to prevent variable gastric emptying. Coating was repeated until to obtain an increase in weight gain of 5%w/w. The % weight gain of capsules before and after coating was determined [8, 11]. The detail of formulation composition is presented in **Table 2.**

Evaluation of designed multiparticulate pulsatile system

Determination of thickness of coating

The thickness was measured by using screw gauge and expressed in mm.

Release behaviour of multiparticulate pulsatile system

Dissolution studies were carried out by using USP type-II dissolution test apparatus (paddle method). Capsules were tied to paddle with a cotton thread so that the capsule should be immersed completely in dissolution media but not float. In order to simulate the pH changes along the GI tract, three dissolution media with pH 1.2 (2 h), 7.4 (3 h) and 6.8 till the end of the study were sequentially used. Nine hundred millilitres of the dissolution medium was used at each time. Rotation speed was 100 rpm and temperature was maintained at 37±0.5 °C. 5 millilitres of dissolution media was withdrawn at predetermined time intervals and fresh dissolution media was replaced. The withdrawn samples were analyzed at 274 nm, by UV absorption spectroscopy and the cumulative percentage release was calculated over the sampling times [8-12].

RESULTS AND DISCUSSION

Aceclofenac sodium is a weak acid; the solubility of aceclofenac sodium in HCl was very less compared with distilled water. However, the addition of surfactant is a reasonable approach for solubilizing such drugs, because various surfactants are present in the GI-fluid. Saturation solubility of aceclofenac sodium in different media increased with an increase in buffer pH as well as with an increase in surfactant concentration. The significant increase is attributed to the

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micellar solubilization by SLS. Aceclofenac sodium showed sufficient solubility in 0.1N HCl with 2% w/v of SLS which was adequate to maintain sink condition and was selected as the dissolution medium for in-vitro drug release studies. The solubility of aceclofenac sodium in calcium chloride was found to be 0.96±1.54 mg/mL.

Drug excipient compatibility testing

The compatibility of aceclofenac sodium with polymer was investigated by IR spectroscopy study as shown in **Figure 1 (a,b)**. The IR spectra of the drug and polymer blends were compared with the spectra of the pure drug and individual polymer spectra. The characteristic absorption peaks of pure aceclofenac sodium were obtained 3276.5, 2915.5, 1716.5, 1589.3 cm^{-1} corresponding to NH- stretching, C=O stretching of –COO and –COOH group respectively**.** The characteristic absorption peaks SA powder showed peaks around 3077.15, 2914.98, 1615.34, 1359.60 and 754.05 cm-1 reflective of O–H, C-H, COO− (asymmetric), COO− (symmetric), and C–O–C stretching respectively. The cross-linking process of sodium alginate with calcium caused an obvious shift to higher wave numbers and a decrease in the intensity of COO− stretching peaks. Additionally, a change to lower wave numbers and a decrease in the intensity of the C–O–C stretching peak of alginate was observed. This indicated the presence of an ionic bond between the calcium ion and the carboxyl groups of sodium alginate and partial covalent bonding between the calcium and oxygen atoms of the ether groups. The physical mixture alginate powder and aceclofenac sodium characteristic peaks were obtained at 2820.28, 1591.72, 1384.91 cm^{-1} caused a shift in the O–H, COO− (asymmetric), and COO− (symmetric) stretching peaks to lower wave numbers, suggesting that a slight molecular interaction between alginate and aceclofenac was formed due to hydrogen bonding and electrostatic force. From the FT-IR study it was clearly evident that the identical FT-IR bands were well retained with no considerable changes in the peaks of drug-polymer physical mixture confirming the absence of potential drug-excipient interactions.

Differential scanning calorimetry (DSC) studies

The thermal behavior of the pure aceclofenac sodium, drug loaded alginate beads were characterized using DSC, as shown in **Figure 2 (a,b).** The thermogram of pure aceclofenac showed a sharp endothermic peak at 156.64^0C followed by corresponding meting point. The obvious peak of the drug (156.64^0C) was observed in the physical mixture but not observed in any type of the prepared microbeads indicating uniform molecular solubility of the drug in polymeric beads. The presence of sharp endothermic melting peak in the physical mixture indicating that there are no changes in thermal behaviour of drug with the excipients used for beads preparation.

Characterizations and Evaluation of Microbeads

Drug-loaded microbeads using natural polymer sodium alginate was successfully prepared and the results were presented in **Table 1**.The mean particle sizes of drug loaded microbeads were performed by optical microscopy and BIS sieves. The mean particle sizes of the alginate formulations (F1-F7) of microbeads were obtained in the range between 596.45±1.04 to 880±1.23 micron. It was found that the particle size distribution was within a narrow size but the mean particle size was different among the formulations. The results indicated that the proportional increase in the mean particle size of microbeads increased with the amount of sodium alginate in the formulations. The total percentage yields of drug-loaded microbeads obtained were in the range between 78.4 to 86.2 %w/w. It was observed that increasing the concentration of sodium alginate in the formulation significantly lower the product yield, due to the formation of high viscous polymer dispersion which may be lost during manufacturing

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process. The drug entrapment efficiency of the loaded microbeads was found to be in the range 65.43±0.42 to 84.5±1.05. The % weight gain of coated beads F2 was found to be 2.2 %w/w.

In-vitro dissolution studies of drug loaded alginate beads

The drug release from uncoated alginate beads was pH independent, showing immediate release in acidic pH 1.2 without any lag time followed by slow sustained release as shown in **Figure 3**. This may be due to the presence of small portion of drug on the surface of the beads which immediately accessible to the media giving rapid solubility. The reason of slower release may be attributed to stability of polymers at lower pHs and conversion of Ca-alginate to the insoluble alginic acid to form tightening of the gel mesh work. On the other hand, the Eudragit L100 coated beads eroded as the pH increases towards alkaline side like 6.8, 7.4 and the contents are released in a sustained manner by both diffusion and slow erosion of polymer matrix. Release study revealed that formulations F1 to F7 were showed the percentage of drug release in pH 6.8 buffer media at the end of 5h was 65.6, 60.7, 55.7, 41.2, 39.2, 27.17and 25.4 respectively. Release data revealed that as the drug-polymer ratio increased, the release rate of aceclofenac sodium from the microbeads decreased. The slower in the release rate can be explained by the increase in the extent for swelling and the gel layer thickness that acted as a barrier for the penetration medium thereby retarding the diffusion of drug from the swollen alginate beads.

Characterization and in-vitro evaluation of designed pulsatile system containing coated alginate microbeads

Results shows that coated alginate microbeads were successfully incorporated in to the pulsatile delivery capsule using different quantities of hydrophilic swellable plugging materials as depicted in **Table 2**. During dissolution studies, it was observed that, the enteric coat of the HPMCP remain intact for 2 h in pH 1.2, but dissolved in intestinal pH, above pH 7.4 leaving the soluble cap of capsule, which also dissolved in pH 7.4, then the exposed polymer plug absorbed the surrounding fluid, swelled and released the drug through the swollen matrix. After complete wetting of the plug, it formed a soft mass, which was then easily ejected out of the capsule body; releasing the eudragit coated microcapsules into pH 6.8 phosphate media buffer. With all the formulations, there was absolutely no drug release in pH 1.2, thus indicating the efficiency of 5% HPMCP for enteric coating. Different concentrations of the swellable polymers such as guar gum, HPMC and carbopol were used and their effect on drug release from the designed pulsatile capsule was investigated using the dissolution media mimicking the pH conditions in the GI tract.

Effect of Different Plugging Materials on In-vitro Release

The in vitro release profile for formulations (a) Sterculia gum (FS1–FS3), (b) HPMC (FH1–FH3) and (c) Carbopol (FC1–FC3) respectively as hydrogel plugging materilas at different proportions are shown in **Figure 4.**. With formulations FS1 (20 mg), FS2 (30 mg), at the end of 5th hour there was 6.38% and 2.15% cumulative drug release was found. In case of FS1 and FS2 it was observed that polymer concentration was sufficient to retard the drug release in small intestinal fluid and the plug ejected out in 6.8 buffers, releasing the entire drug in large intestine, in a controlled manner. At the end of 24 h, 92.22%, 94.14%, 87.18% of drug release was found in FS1, FS2 and FS3 respectively. With formulation FH1 (20 mg), FH2 (30 mg), at the end of 5th hour 5.33% and 4.26% of drug was released respectively and at the end of 20th hour FH1 formulation had released 94.47% of drug, whereas FH2 formulation released 90.42% of drug up to 24 h in controlled manner. In case of FH3 (40 mg), hydrogel plug ejected out in between 6th and 8th hour, indicating decrease in expelling power of plug. At the end of 24th hour 86.43% of drug was released. For the formulations FC1, FC2 and FC3 Carbopol was employed as plugging

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material in three different concentrations like 20, 30 and 40 mg respectively. With these formulations 96.56, 86.30% and 77.80% of drug was released at the end of 16th hr. This virtually indicated the failure of these formulations in maintaining the desired lag phase and also failed to maintain the drug release for a period of 24 hrs.

Table 1: Detail composition of aceclofenac loaded calcium alginate beads

Batch Code	Drug/ Polymer ratio	Sodium alginate (%w/v)	Conc.of $CaCl_2$ (%) w/v	Curing Time (mins)	Mean Particle Size (micron)	% Yield	% DEE
F1	1:1	2	5.0	30	596±1.04	86.2	65.43±0.42
F2	1:2	2.5	5.0	30	631±1.12	82.1	76.5±0.12
F3	1:2.5	3.0	5.0	30	667±1.54	84.5	76.8±0.21
F4	1:2.75	3.5	5.0	30	710±1.21	81.5	78.5±0.47
F5	1:3	4.0	5.0	30	764±0.44	81.2	81.2±1.02
F6	1:3.5	4.5	5.0	30	810±0.24	80.5	82.4±1.12
F7	1:4	5.0	5.0	30	860±1.14	78.4	84.5±1.03

Table 2. Composition of proposed pulsatile system based on design summary

Batch Code	Wt. of empty Cap. body (mg)	Wt of eudragit coated alginate microbeads (mg)	Wt. of gelatin Cap.(Non-formal dehyde treated)	Swellable plugging materials	Wt. of plugging material (mg)	Total wt. of capsule (mg)	Wt. after HPMCP Coating (mg)
FS1	78	362	47	Sterculia Gum	20	503	538
FS2	79	362	45	SterculiaGum	30	519	558
FS3	78	362	46	Sterculia Gum	40	533	570
FH1	80	362	46	HPMC	20	505	541
FH2	81	362	45	HPMC	30	521	559
FH3	80	362	47	HPMC	40	535	573
FC1	80	362	47	Carbopol	20	505	541
FC2	79	362	46	Carbopol	30	519	559
FC3	80	362	47	Carbopol	40	536	574

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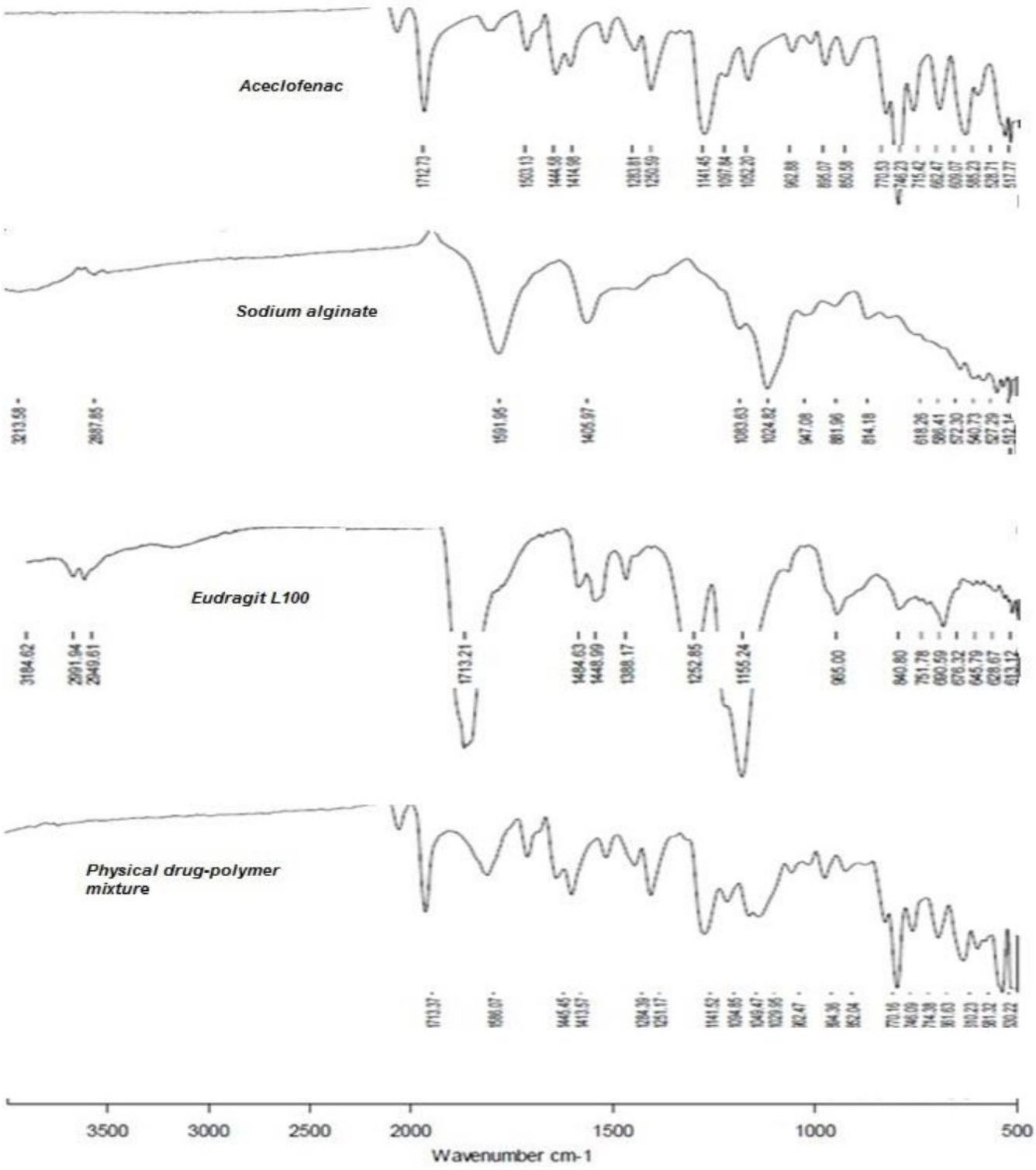

Figure 1 (a). Comparative FT-IR spectrum of aceclofenac, sodium alginate, Eudragit L100 and drug-polymer physical mixture

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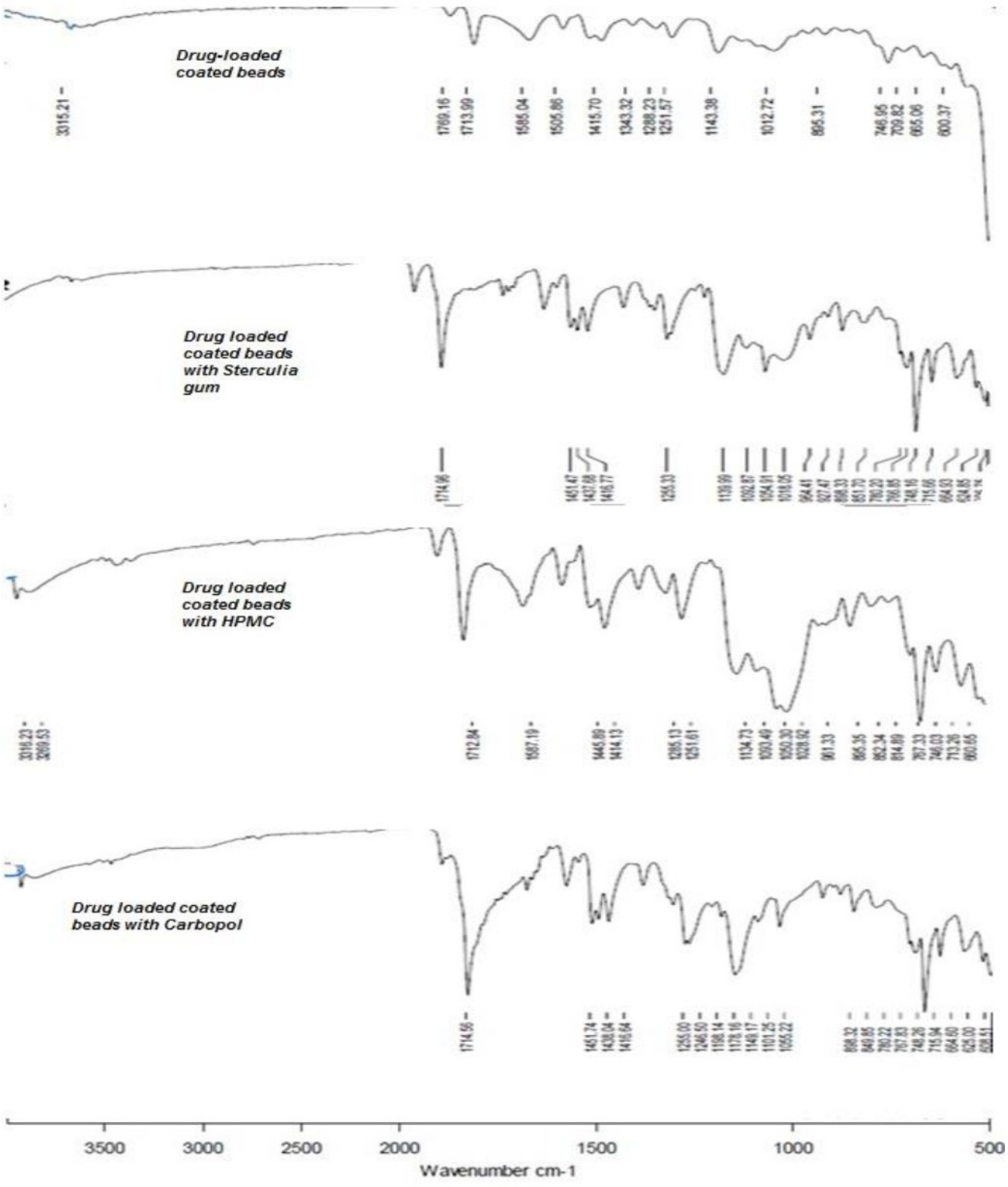

Figure 1 (b). Comparative FT-IR spectrum of Eudragit L100 coated alginate beads, coated beads with plugging materials (Sterculia gum, HPMC, Carbopol).

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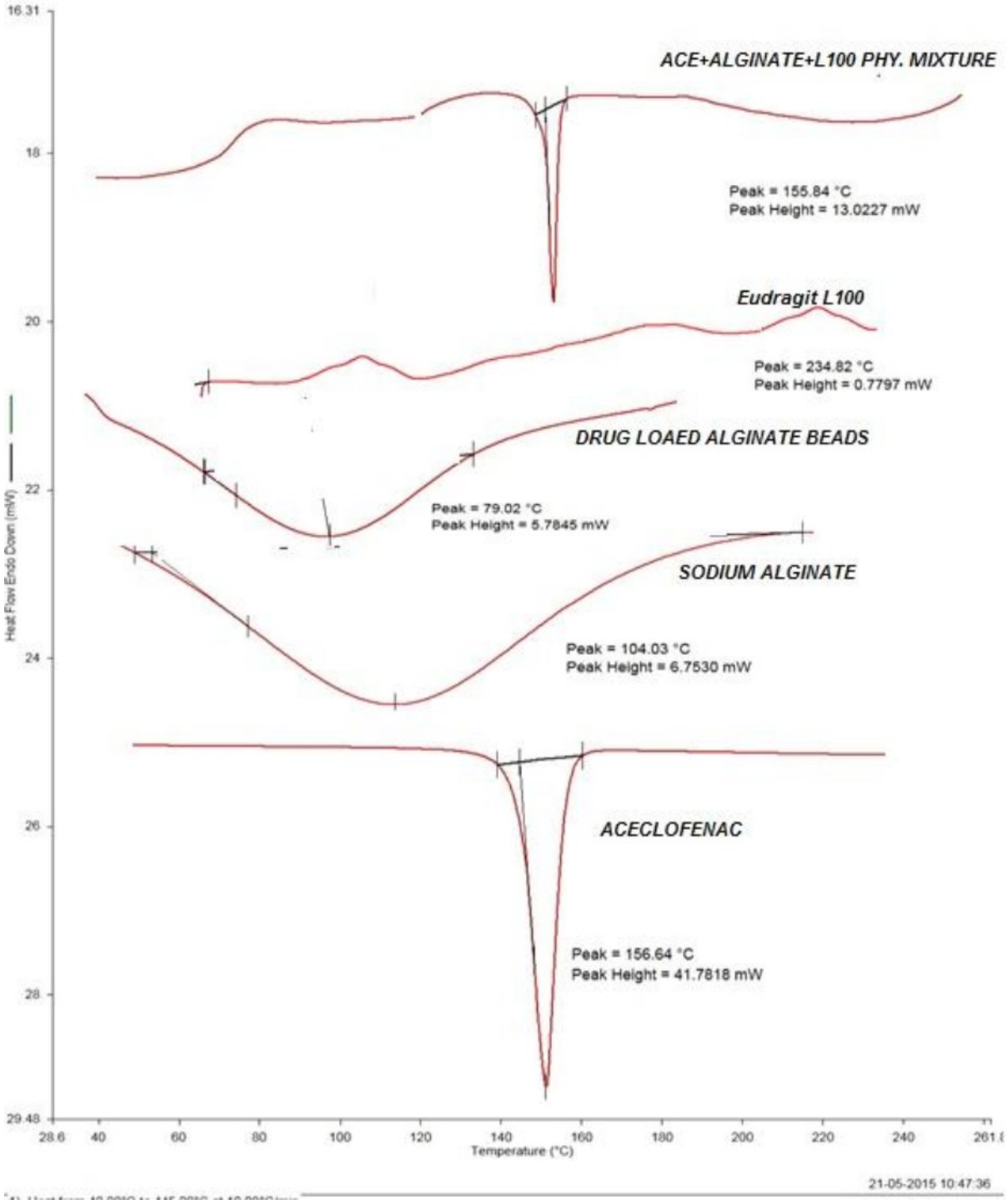

Figure 2 (a). DSC thermogram of pure drug, sodium alginate, Eudragit L100, drug-polymers physical mixture and eudragit coated drug-loaded alginate beads

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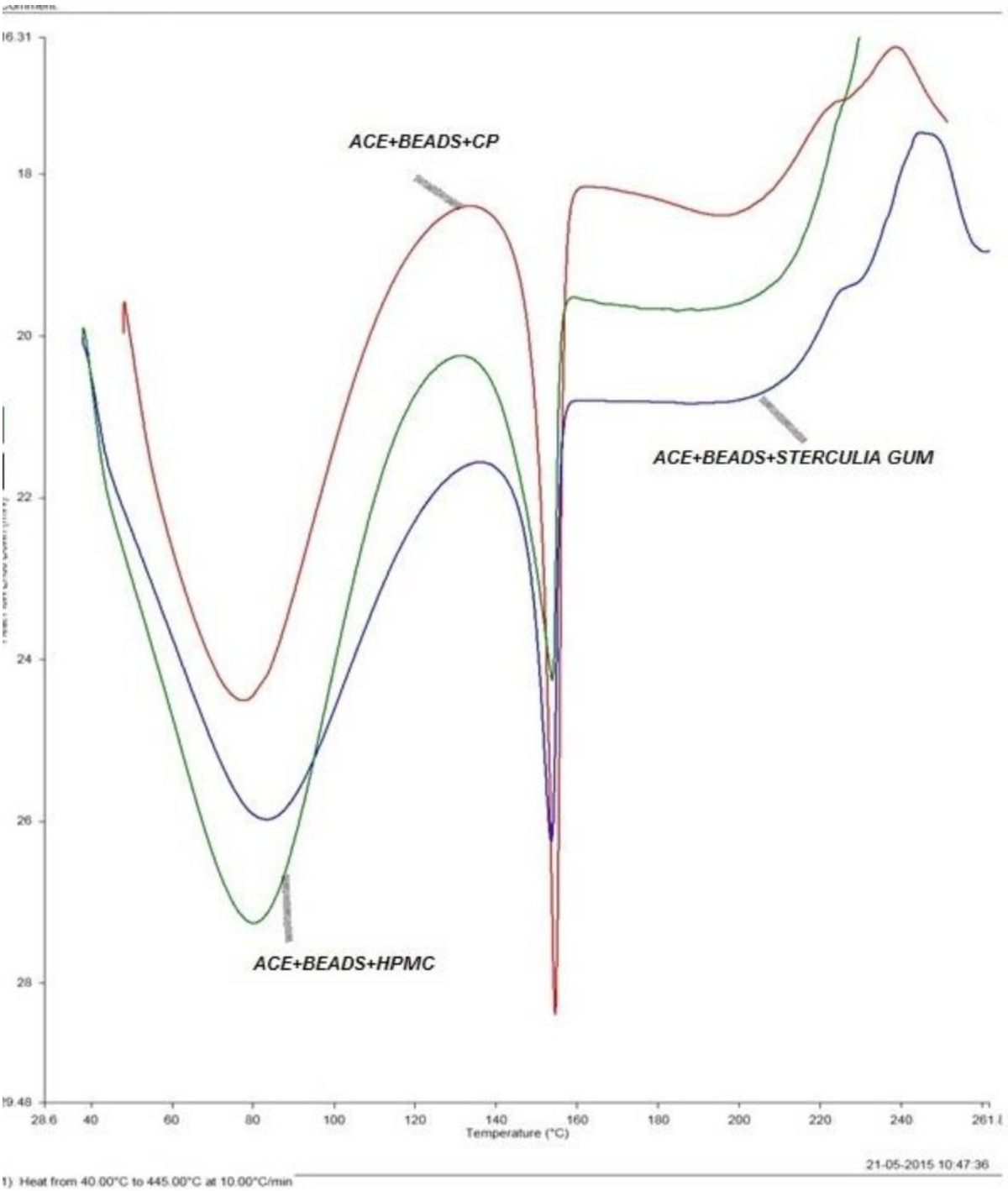

Figure 2 (b). Comparative DSC thermogram of Eudragit L100 coated alginate beads with plugging materials (Sterculia gum, HPMC, Carbopol).

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Figure 3. Comparative in-vitro drug release profile of coated alginate microbeads (F1-F7) in phosphate buffer media pH 6.8.

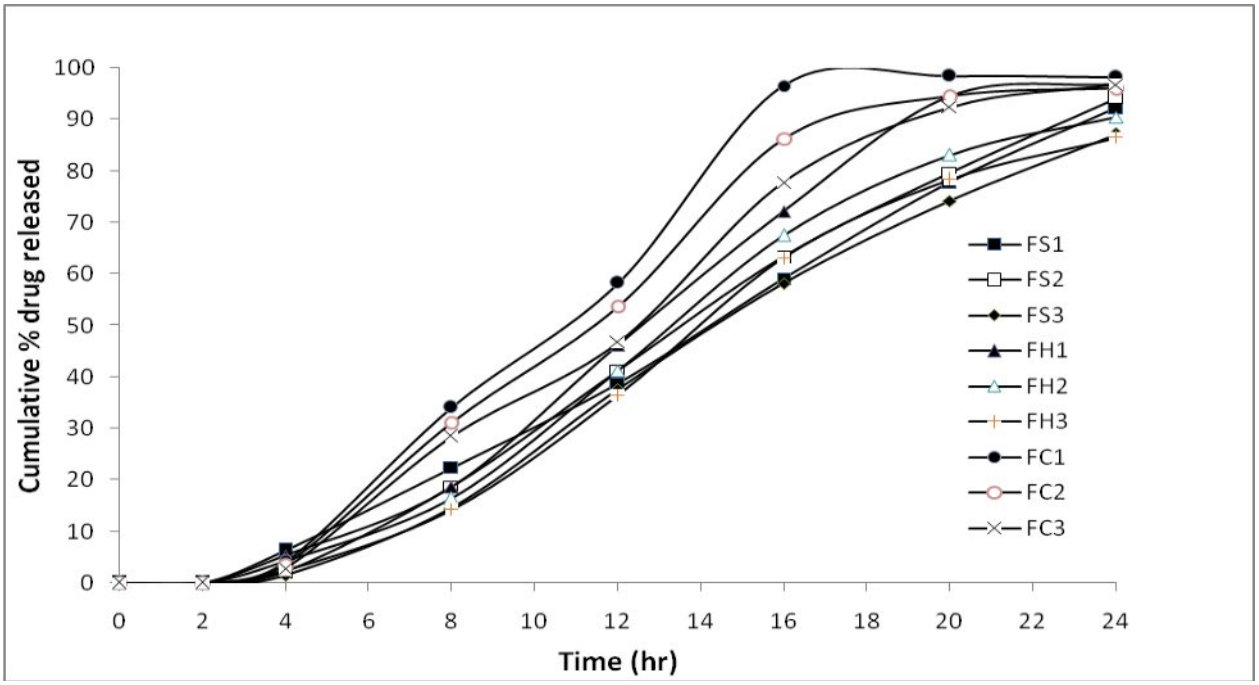

Figure 3. Comparative in-vitro drug release profile of aceclofenac from multiparticulate pulsatile system containing varying quantity of hydrophilic plugging materials (FS1-FS3, FH1-FH3, FC1-FC3) in pH 1.2, 7.4 and 6.8.

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CONCLUSIONS

In conclusion, ionotropic gelation technique can be successfully used for preparation of aceclofenac sodium microbeads and the microbeads showed good in-vitro release characteristics when incorporated in to the pulsatile system as final dosage form. With all the above observations, it was found that Sterculia gum and HPMC as plugging materials were found better in maintaining the desired lag period compared to Carbopol. The rank order of sustaining capacity of polymer was Sterculia gum>HPMC>Carbopol. It was also observed that the plug was ejected only at the end of 6 hours of dissolution and released variable amount of drug. The lag period and the drug release could be efficiently modulated by altering the concentration of plugging material to a certain extent. Thus, the study reveals the efficacy and suitability of these natural polymers as plugging materials in the design of chronotherapeutic delivery of aceclofenac and appears to be effective delivery system for the treatment of rheumatoid arthritis.

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