Formulation & Evaluation Of Piroxicam Bionanocomposite For Enhancement Of Bioavailability

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ABSTRACT

Water solubility is an essential physicochemical property of drug. For a drug molecule to reach the systemic circulation and to exert the therapeutic effect it must be in aqueous solution form. Solubility and dissolution enhancement of poorly water soluble drug piroxicam is done by formulating bionanocomposites (BNCs) using microwave induced diffusion (MIND) which leads to the enhancement of bioavailability. The BNCs were prepared by using various natural polymers such as Ghatti gum, Acacia and Guar gum with the help of microwave oven. Polymer selection was done on the basis of their surfactant and wetting properties. The studies such as foaming index, swelling index and viscosity determination carried out for characterization of natural polymer. The best ratio of drug to polymer was selected for the optimization of the formulation on the basis of their solubility and dissolution data. The BNCGGPRX showed best results regarding solubility and dissolution enhancement and hence selected for the formulation of tablets. The characterization of BNCs were carried out by Fourier Transform Infrared Spectroscopy (FT-IR), Differential scanning calorimetry (DSC), X-ray diffraction study (XRD), scanning electron microscopy (SEM) and Transmission electron microscopy (TEM). The MIND method gives a perfect means of solubilisation by generating drug dispersion at the micro and nanoscale level in natural biodegradable polymer. Hence, this study demonstrates the use of BNCs in solubility and dissolution enhancement.

Keywords:

Bionanocomposite, Solubility enhancement, Dissolution enhancement, Piroxicam, BCS Class II drug.

INTRODUCTION

Dissolvability of drug is most interesting perspectives in the plan and improvement. Drug effectiveness can be seriously restricted by poor aqueous solvency, and most of the drug additionally show incidental effects because of their poor dissolvability. Expanding drug solvency builds the viability and diminishes results of specific drugs. Drugs having poor water solvency are connected with the sluggish medication assimilation lastly deficient or various bioavailability. As of now, almost 40% of recently integrated drugs have issue of poor water solvency. The diminished watery dissolvability of medication in the gastrointestinal fluid frequently causes deficient bioavailability. These drugs require high portion to accomplish restorative plasma focus. For oral administration of drug, it is fundamental that it ought to be in a watery structure at the site of activity.[1-3] The Biopharmaceutical Classification System (BCS) classified drugs into four categories according to the solubility and permeability. Class II BCS drugs exhibit high permeability and low solubility. Most of the non-steroidal anti-inflammatory drugs (NSAIDs) belong to the BCS Class II. They are greatly permeable through biological membrane but have limitation of poor aqueous solubility. The rate of drug absorption and bioavailability of such poorly water-soluble drugs are controlled by rate of dissolution in gastrointestinal fluids. This problem has been tried to resolve by many researchers by various methods in the past to enhance solubility and dissolution ultimately bioavailability. [4-5] Piroxicam is poorly aqueous soluble (0.023mg/ml) which results in poor dissolution rate and reduces in its gastrointestinal absorption. Oral route is the most common way of drug delivery system for drug administration. The majority of sold pharmaceutical products (drugs) are given orally.[6-7] A key objective in the development of oral dosage forms is a good understanding of the in vivo and in vitro performance of the dosage from. The increase in surface area by particle size reduction increases dissolution property. Nanosize means the particle size between 100 to 1000 nm.[8] BNCs produce improved saturation solubility and therefore shows increased dissolution velocity. Continuous advancement in the other drug delivery system leads to pay attention toward oral drug delivery system to enhance clinical efficiency and patient compliance. From pharmaceutical point of view, a numerous types of polymer are used to control drug release as of dosage form. The use of natural polymer rather than synthetic polymer is additionally preferred. Natural polymers are mainly used since they are readily available, inexpensive, nonreactive, capable of chemical modification, and potentially well suited and degradable.[3] Due to the development of polymer based BNCs, these are extensively used in the pharmaceutical manufacturing. Polymer BNCs are the polymer that has been reinforced with small quantities of nanosize particles having high characteristic ratio. In this study, we have used novel technique called microwave induced diffusion (MIND) which is green and cost-effective for the production of BNCs. Microwave heating starts from the direct interaction of electromagnetic force with the material. The extent to which the material is heated by microwave energy is reliant on the range of parameters, but particularly dielectric properties are more significant. Polar liquids such as water are very readily heated. Microwave heating can confer a number of benefits over conventional heating, which includes rapid heating and cooling, reduced temperature gradients across the sample, lower energy practice, and enhanced reaction rates. BNC is the process of complex formation between drug and natural polymers (acacia, guar gum and ghatti gum) where microwave energy plays a significant role in reducing particle size of materials. It breaks intermolecular bonding and reduces the particle size. Nowadays, microwaves also applied for reducing particle size of drug material up to nanometer (nm). Reduction in particle size increases efficient surface area of the drug and thereby enhances solubility and dissolution rate. In the present study, Piroxicam BNCs formation enhances solubility which ultimately

leads to increase in bioavailability of the drug. Microwave heating is a well-established method for processing and drying.[9-10] The natural polymer acacia, guar gum and gum ghatti are used for the formation of different BNCs. Piroxicam is an active component of NSAIDs. Piroxicam is a 4-hydroxy-2-methyl-N-2-pyridinyl-2H-1, 2-benzothiazine-3carboxamide-1, 1-Dioxide which is used as rheumatoid arthritis, osteoarthritis and ankylosing spondylitis. Most of the NSAIDs are Class II drugs according to BCS. They are highly permeable through biological membrane but possess low aqueous solubility.[6-7] Therefore, it is needed to enhance the solubility and dissolution ultimately bioavailability of Piroxicam.

MATERIAL AND METHOD

Piroxicam drug was obtained as gift sample from Maxheal pharmaceutical (India) Ldt. Acacia, Ghatti gum and Guar gum were brought from SD Fine Chemicals (Mumbai, Maharashtra, India). The microcrystalline cellulose, sodium starch glycolate, talc, and magnesium stearate were purchased from the SD Fine Chemicals (Mumbai, Maharashtra, India). Methanol, hydrochloric acid, and sodium dihydrogen phosphate were analytical grade.

SOLUBILITY STUDY [11]

The solubility of drugs was determined by taking an excess amount of drug and adding them to 10 ml of solvent, in Teflon-facing screw-capped vials. The samples were kept at equilibrium for a period of 24 h on an orbital shaking incubator (CIS-24; Remi Instruments, Mumbai, India) at $37\pm0.5°C$ and 50 rpm. The supernatant liquid were collected and filtered through 0.2μ membrane filter and analyzed by UV-Visible spectrophotometer at wavelength 354 nm.

CHARACTERIZATION OF POLYMER

➢ **Swelling Index (SI)** [12-13]

Swelling index of gums was determined by modified method reported. 1gm of Acacia, Ghatti gum, and Guar gum was accurately measured and transferred to 100 ml measuring cylinder. The initial volume occupied by gum was noted. The volume was made up to the 100ml with distilled water. The open end of cylinder was sealed with aluminum foil and kept aside for 24 hrs. After 24 hrs volume of swelled gum was noted. The swelling index of gum was calculated by the following formula. Swelling index (SI)

$$SI = \frac{H_f - H_i}{H_i} \times 100$$

Where, SI- Swelling index of gum; Hi- Initial height of powder; Hf- Final height of powder after 24 hr

➢ **Foaming index**

The foaming index of gum was calculated to check the surfactant properties of the gum. Surfactant property of gums can be determined by foaming index. Accurately weighed 1 g of gum and transfer it in 250 ml measuring cylinder. 100 ml distilled water was added in measuring cylinder to make dispersion. Resultant dispersion was vigorously shaken for 2 minutes. The foaming index of gum calculated by the following equation.
Foaming index = Hf – Hi
Where, Hf = Height of solution of gum after shaking; Hi = Height of solution of gum before shaking.

➢ **Viscosity**

Viscosity of gum were calculated by taking one gram of each Guar gum, Acacia gum and Ghatti gum.

PREPARATION OF PHYSICAL MIXTURE [14]

Physical mixture of drug with polymer Acacia (AC), Guar gum (G_RG), Ghatti gum (GG) were prepared by simple blending of drug with gum in the ratio1:1 to 1:3 .The physical mixture of drug with polymer were denoted by symbol (PHYACPRX), (PHYG$_R$GPRX),and (PHYGGPRX).

PREPARATION OF BIONANOCOMPOSITES [5]

The bionanocomposites were prepared by homogenous mixing of accurately weighed amount of individual drug with individual polymer. In this case the weight to weight (W/W) ratio of drug to polymer was taken from 1 to 3 keeping amount of mixture constant. To this mixture 5 mL of water was added for each gram of polymer to make homogenous slurry. The fixed amount of slurry 5gm was taken in glass beaker and irradiated with microwave radiation at power 640 (power grill 20 black, ONIDA) with continuous stirring. Bionanocomposites were grounded in mortar and pestle to obtain the size of 80 to 250 µm. The bionanocomposites of drug with polymer were denoted by symbol BNCGGPRX, BNCACPRX, and BNCG$_R$GPRX.

Physical mixture   **Microwave heating**   **Intermediate product**   **BNCs**
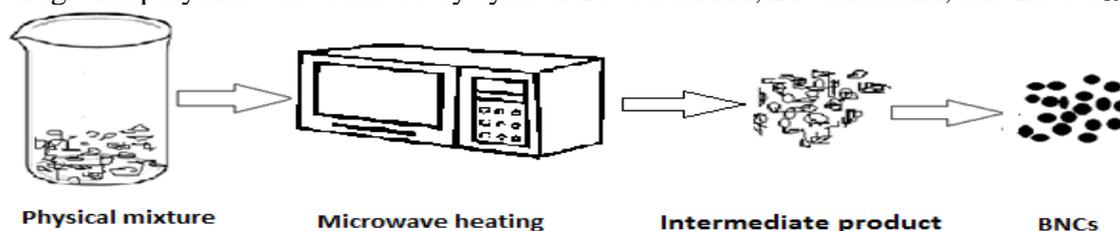
Figure 1 Preparation of microwave assisted BNCs

RATIO OPTIMIZATION (DRUG: POLYMER) BY SOLUBILITY

BNCs samples equivalent to 10 mg of BNCACPRX, BNCG$_R$GPRX, BNCGGPRX were placed in 10 ml water in Teflon facing screw capped vial and kept at equilibrium for 24 hr on orbital shaking incubator (CIS-24; Remi Instruments, Mumbai, India)) at $37\pm0.5°C$ and 50 rpm. The content of vials were filtered through 0.2 micron filter and analyzed by UV-Visible spectrophotometer at 354 nm. As the concentration of polymer increases also increase in the drug solubility. The optimized ratio of was found to be 1:3 w/w BNC's of Ghatti gum (GG)

CHARACTERIZATION

BNC's which showed better result upon solubility and dissolution studies were selected for further characterization. The characterization of BNC's was performed to asses interaction between drug and polymer.

Fourier-Transform infrared spectroscopy (FT-IR) [15]

FT-IR spectra of pure drug Piroxicam (PR), pure polymer (AC, GRG, GG) and BNC's of drug with individual polymer were taken to check the compatibility of drug with polymer. Bionanocomposites of drug with polymer was mixed with potassium bromide (KBr) of IR grade in the ratio of 1:100. The pellets were then scanned using FT-IR Spectrophotometer (SHIMADZU DR-8031 Japan) the wavelength ranged from 400-4000 cm.

Differential Scanning calorimetry (DSC) [16]

DCS studies of pure drug piroxicam and bionanocomposites of drug with polymer (Ghatti gum) were employed to access what changed had actually made when bionanocomposites were formulated and by what fact these enhances the solubility of drug. The DSC curves were obtained by Differential Scanning Calorimeter (DSC 60, Shimadzu, Japan) at the heating rate of 10°C/ min from 0 to 300° in nitrogen atmosphere.

X-ray diffraction studies (XRD) [17]
XRD studies of drug piroxicam and nanocomposites of drug with polymer (Ghatti gum) were carried out to investigate the change in crystallinity when drug was mixed polymer. XRD pattern were recorded using (Miniflex II, Rigaku) with Cu-kα radiation. The scanning angle ranged from 10° to 50° of 2θ.

Scanning electron microscopy (SEM) [18]
Scanning electron microscopy was used to examine external surface morphology. The morphologies and detailed particle structural characterizations of pure drug and bionanocomposites were observed by scanning electron microscope (JEOL Model JSM-6390LV).

Transmission electron microscopy (TEM) [19]
The particle size and shape of pure drug crystal dispersed in polymer were analyzed with Transmission electron microscopy. The morphology of the BNCs were obtained by JEOL/JEM 2100 Transmission electron microscope (TEM) (STIC INDIA Cochin)

Size distribution analysis
Bionanocomposites formulation containing accurate dose of drug was diluted with 20ml distilled water and was then mixed gently by inverting the flask. The particle so formed was determined by dynamic light scattering (DLS) technique using zetasizer (Nanophox NX0088).

Formulation of immediate release tablet
The optimized ratio of bionanocomposites which shown superior result in solubility and dissolution studies was selected for preparation of immediate release tablet. Bionanocomposite of drug with Ghatti gum was selected for formulation of immediate release tablet using superdisintegrant. The composition used for tablet formulation are given in the table no. 1 All the components of tablet were passed through sieve no.60 accurately weighed, mixed and compressed into tablet 9 mm punch. (Karnavati Engineering Ltd. Gujarat)

Table 1 Preparation of immediate release tablet of piroxicam

Sr. No	Ingredients	F1	F2	F3	F4
1.	BNCGGPRX	80	80	80	80
2.	Microcrystalline cellulose	110	108	110	108
3.	Sodium starch glycolate	6	6	8	8
4.	Magnesium stearate	2	2	2	2
5.	Talc	2	2	2	2

EVALUATIONOF IMMEDIATE RELEASE TABLET [20-21]
Pre-compression evaluation

Precompression evaluation includes measurement of angle of repose, Carr's index (Compressibility index), and Hausner's ratio of optimized bionanocomposites and formulation mixture.

Post-compression evaluation

Post compression evaluation involves the measurement of weight variation, Friability, Disintegration test, Hardness, Drug content analysis all these tests were performed as per the procedure given in the USP 30 (2007)

In vitro dissolution test

In vitro dissolution test was performed according to USP XXIV apparatus 2 (paddle) methods. 900 mL of 0.1 N HCL was used as dissolution media. Tablets of various batches were added to the dissolution media maintaining the temperature $37 \pm 0.5°C$ and rotation speed of paddle at 50 rpm. 5 ml aliquots were withdrawn at 5, 10, 15, 30, 45, 60 minutes time intervals. The volume was maintained by adding 5 ml of fresh dissolution medium. Samples were filtered through 0.2 micron filter and analyzed spectrophotometrically at wavelength of 333 nm.

RESULT AND DISCUSSION

Solubility studies

The solubility of piroxicam in water was found to be 0.0489 mg/ml.
Physical characterization of polymer

Gum characterizations are carried out by checking their swelling index, foaming index, viscosity. The gum having the less viscosity and high foaming index are preferred as best candidate for the formulation shown in table 2.

Table 2: Physical characterization of polymer

GUM	% SWELLING	VISCOSITY	FOAMING INDEX
Ghatti gum	70.83 ± 1.67	3.721 ± 1.29	18 ± 0.96
Acacia	72.72 ± 1.20	4.351 ± 1.27	17 ± 0.40
Guar gum	71.18 ± 0.85	5.271 ± 1.65	15 ± 0.70

Data are means $\pm$ SD, n=3

Solubility of physical mixture
The drug:carrier ratio was optimized from the outcome of solubility study. The solubility study showed that AC, GRG and GG enhance solubility. Solubility studies of physical mixtures and BNCs clearly indicated that the ratio of drug to polymer increases solubility. No significant increase in solubility was shown after 1:3 ratio of drug to polymer, so 1:3 ratio was optimized shown in figure 2. This optimized ratio was then confirmed with powder dissolution and found to be increased in solubility. Enhancement of solubility with PHYGGPRX 537.8 ± 0.95 µ/ml was established to be more than PHYACPRX and PHYGRGPRX 514.2 ± 1.04 and 515.7 ± 0.95 µ/ml respectively by physical mixture, BNCGGPRX 730.0 ± 1.06µ/ml was established to be more than BNCACPRX and BNCGRGPRX 647.8 ± 1.69 and 631.5 ± 0.60 µ/ml respectively by BNCs; this may be due to more foaming index of GG than AC and GRG.
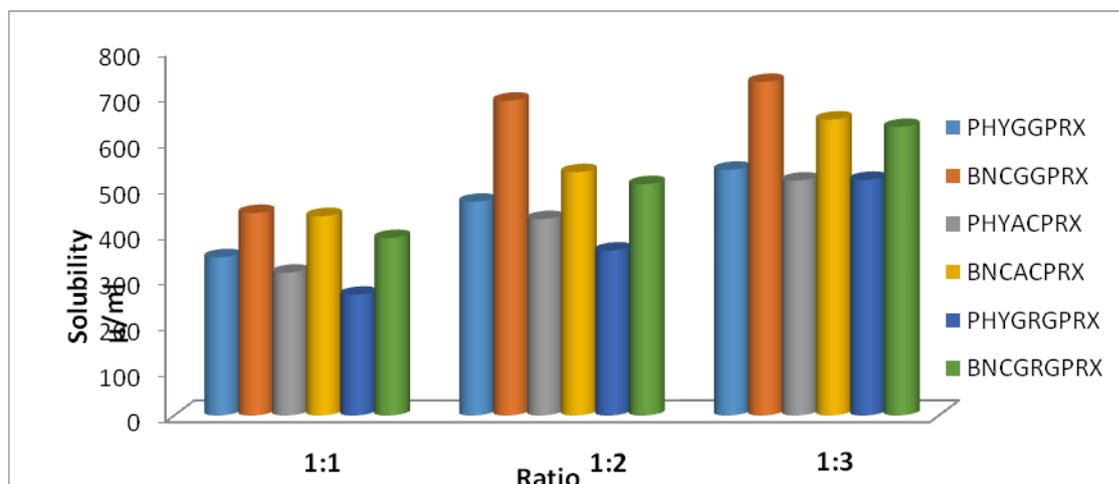
Figure 2 Solubility graphs of PHYGGPRX, PHYACPRX, PHYGRGPRX, BNCGGPRX, BNCACPRX, and BNCG$_R$GPRX in distilled water

In-vitro dissolution of powder formulation of pure drug and BNCs
The powder dissolution test was performed to check solubility enhancing properties of the materials. The dissolution profile of BNCs showed notable improvement in the dissolution rate in Piroxicam BNCs when compared with the pure Piroxicam. BNCs of Piroxicam with GG demonstrated good result. It released 92.43% in comparison to pure Piroxicam which released 55.93% after 60 min. On the basis of obtained results of solubility and dissolution studies, BNCGGPRX was selected to formulate the tablet. The dissolution profile of Piroxicam and Piroxicam BNCs is shown in Figure 3. Therefore, it can be concluded that dissolution rate of KE drug has been enhanced with BNCs.
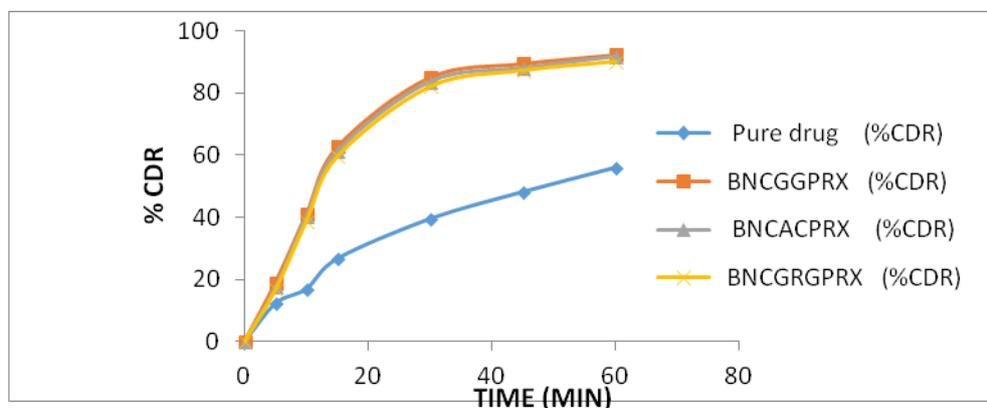
**Figure 3.** Powder In-vitro dissolution test of pure Piroxicam, BNCGGPRX, BNCACPRX and BNCG$_R$GPRX

Drug content analysis of Bionanocomposite
Uniform dispersion of drug in the bionanocomposite can be determined by drug content analysis. It was found that 96-99% drug was incorporated in the bionanocomposite showing uniform dispersion of drug in the bionanocomposite.

FT-IR Studies
FT-IR studies are carried out for characterization of drug and to check the interaction between drug and polymers. FT-IR studies of pure drugs, and individual drug with individual

polymer (GG, AC, G$_R$G) is carried out. FTIR spectra of pure drug and bionanocomposite are shown in the following figure 4.
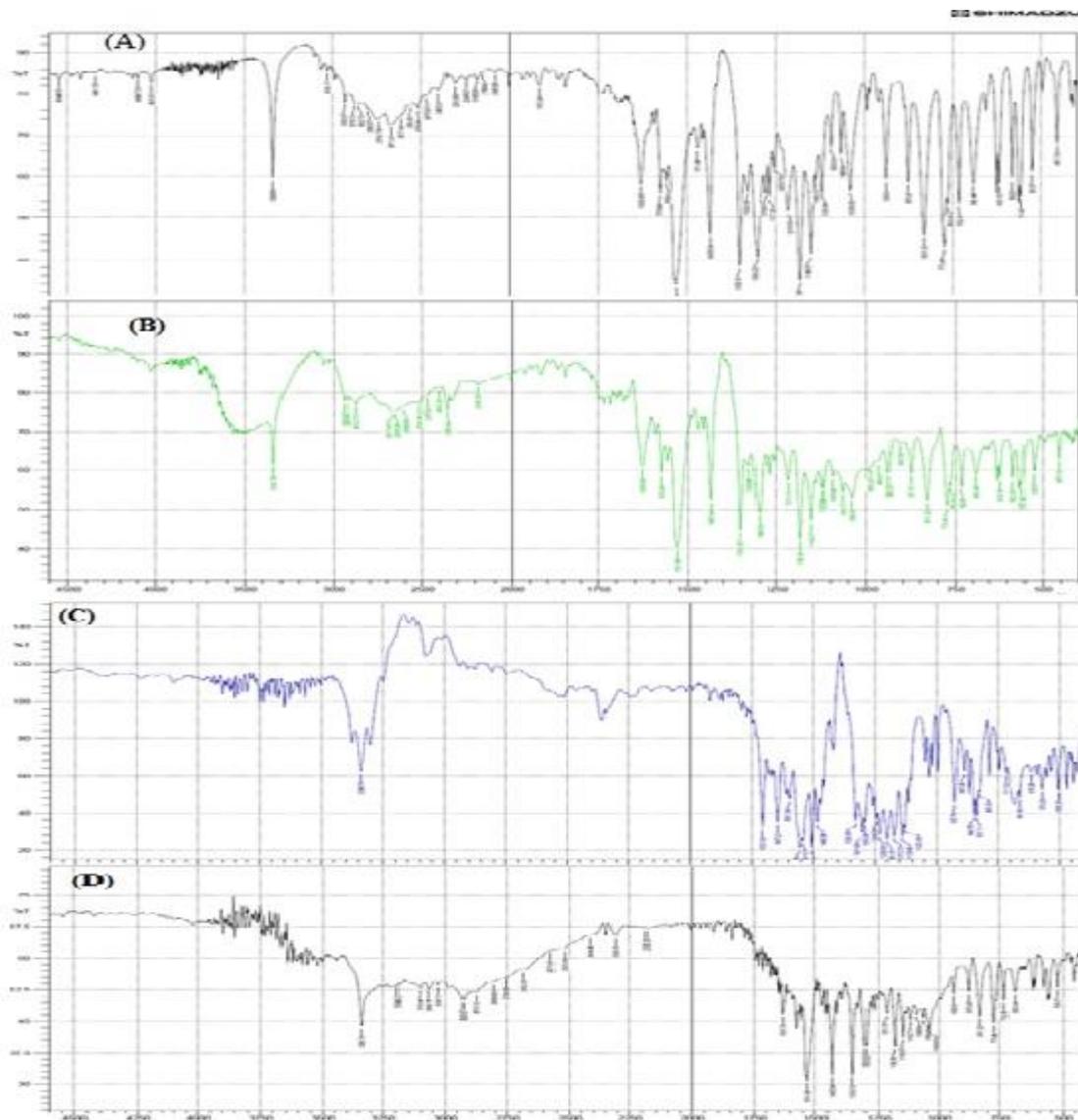
**Figure 4** FT-IR Spectra of (A) pure drug piroxicam (B) BNCGGPRX (C) BNCACPRX (D) BNCG$_R$GPRX

FT-IR spectra of piroxicam exhibit all reported characteristic peaks, N-H stretching at 3338.78 cm^{-1}, C=O stretching at 1629.85 cm^{-1}, C-S stretching at 692.44, S(=C)$_2$ cm^{-1} stretching at 1352.10 cm^{-1}, Aromatic C-H stretching at 3030.17 cm^{-1} and C=C stretching at 1435.04 cm^{-1}.

From the FT-IR spectra of BNCGGPRX, BNCACPRX and BNCG$_R$GPRX these are observed that principle peak value of pure drug remain unchanged in the microwave treated BNCs. Hence it can be conclude that there is no interaction between drug and polymer.

DSC Studies

The DSC thermogram of pure drug shows a sharp endothermic peak corresponding to the melting point of crystalline drug was to at 202.34°c. DSC of BNCGGPRX shows slight variation in endothermic peak as that of pure drug and intensity of peak is reduced this may be due to the decrease in the crystalline size of the drug. Small reduction in melting point and

broadening of peak indicate reduction of drug to nanocrystalline form. As there is a slight variation in the melting point of drug and polymer it will indicate that there is no interaction between drug and polymer. DSC was performed to detect the interaction between piroxicam and polymer shown in figure 5.
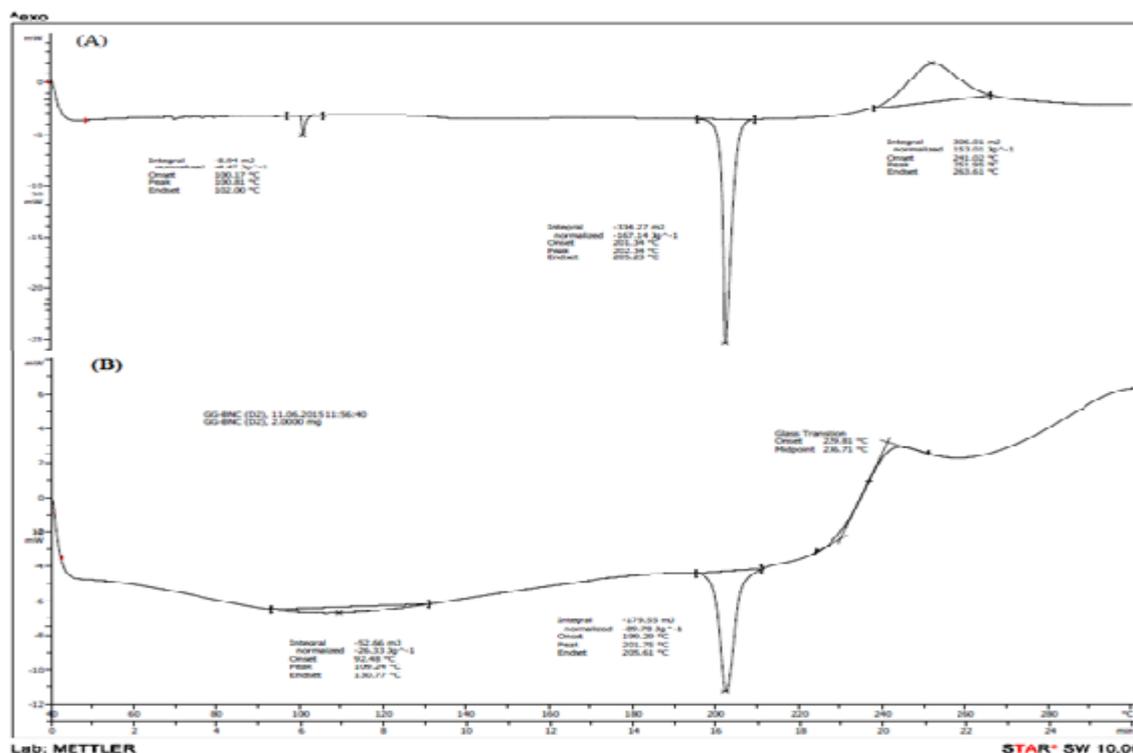
Figure 5 DSC Graphs of (A) pure Piroxicam and (B) BNCGGPRX

X-Ray diffraction studies

The X-ray diffraction studies (XRD) of piroxicam (PRX) and BNCGGPRX are shown in figure. The pure (PRX) exhibit intense crystalline peak between 10° and 50°, characteristic diffraction peaks at 12.33°, 14.71°, 16.11°, 17.88°, 21.96°, 27.50°and 29.40° were observed with intense peak at 17.88° indicating the crystalline nature of PRX. On the other hand BNCGGPRX it's observed that the peak intensity is reduced indicating reduction in crystallinity. XRD was performed to detect the interaction between piroxicam and polymer shown in figure 6.
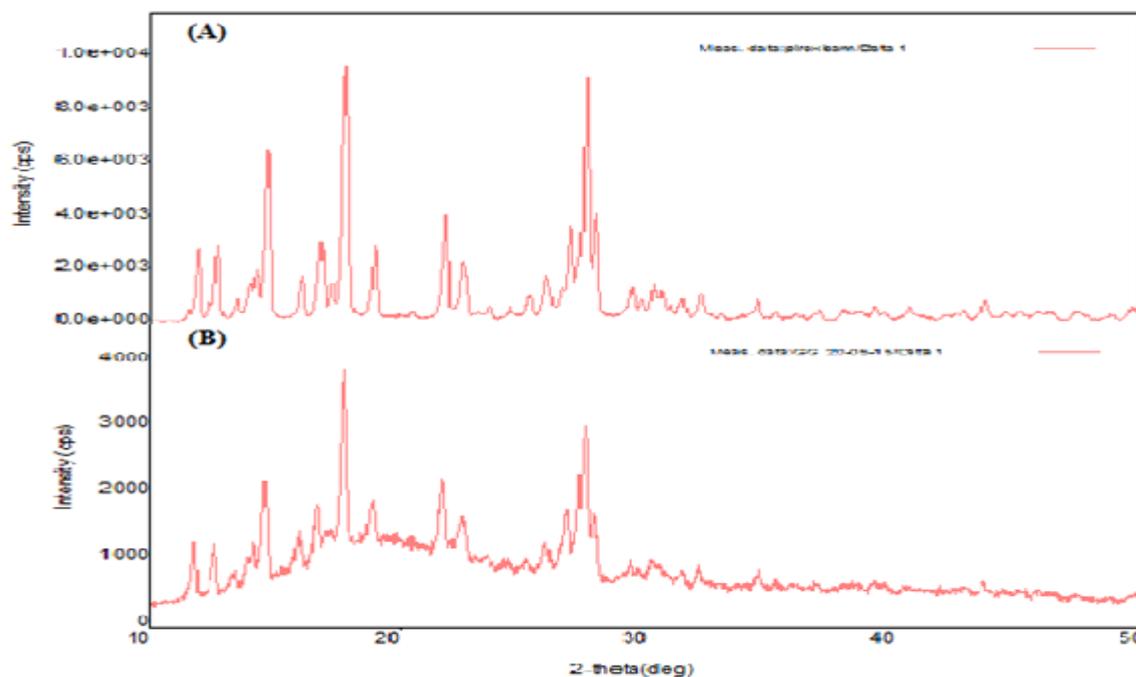
Figure 6 XRD of (A) Pure Piroxicam and (B) BNCGGPRX

Scanning Electron microscopy (SEM)

The SEM studies are generally carried out to identify the surface morphology of drug particles. The morphological characteristics of drug and BNCGGPRX are shown in figure 7. From the below figure it is conclude that shape of pure PRX shows cubic and plate shaped with smooth surface while in case of BNCGGPRX it was observed that they were irregular shape and size.
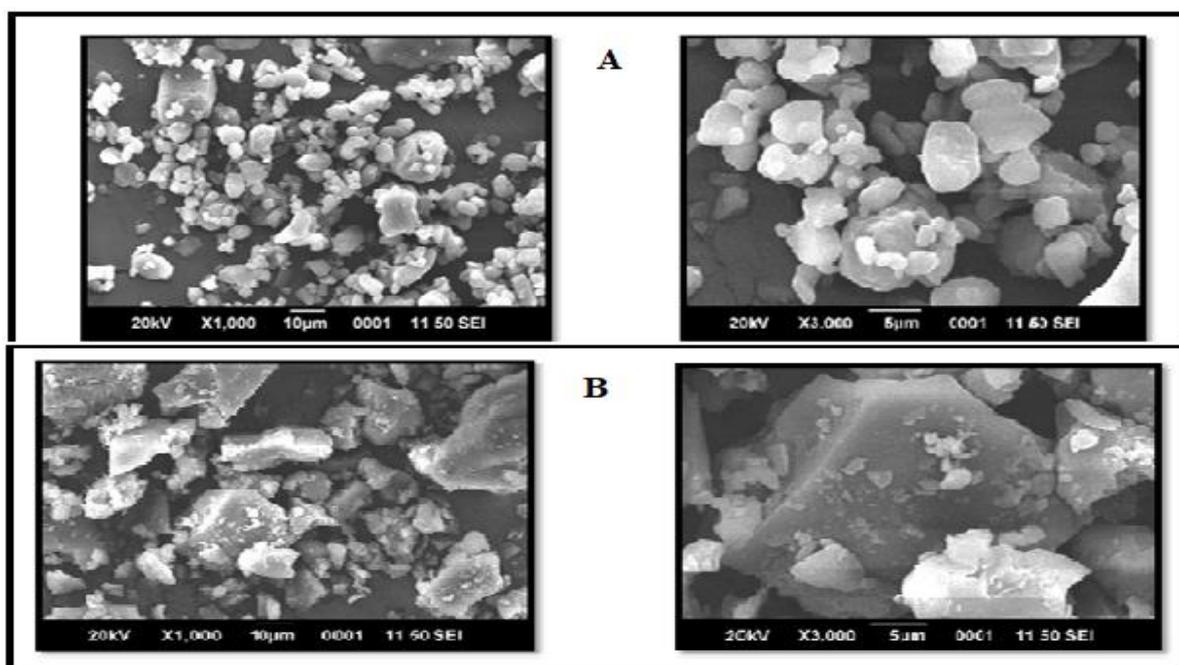
Figure 7 SEM images of (A) pure drug (B) BNCGGPRX drug

Transmission electron microscopy (TEM)

The TEM image of drug was observed first at 200 nm. In that image the drug is showing dark colour particles and pure drug image of TEM at 100 nm the large free particles can be observed in somewhat cubic and rod shaped structure. After preparation of BNCGGPRX in which drug and polymer is mostly mixed looking flowery and most of the drug has transformed with the polymer. The polymer background which has more brightens and therefore drug is looking on the surface of polymer at 50 nm. When this preparation is observed at 20 nm the polymer is in background and the rod shaped structure of drug has converted into somewhat square shaped which shows that there is reduction of particle size of drug when it was treated with MIND method and all drug and polymer are finely embedded in each other. The TEM of pure drug and BNCGGPRX are shown in the figure 8.
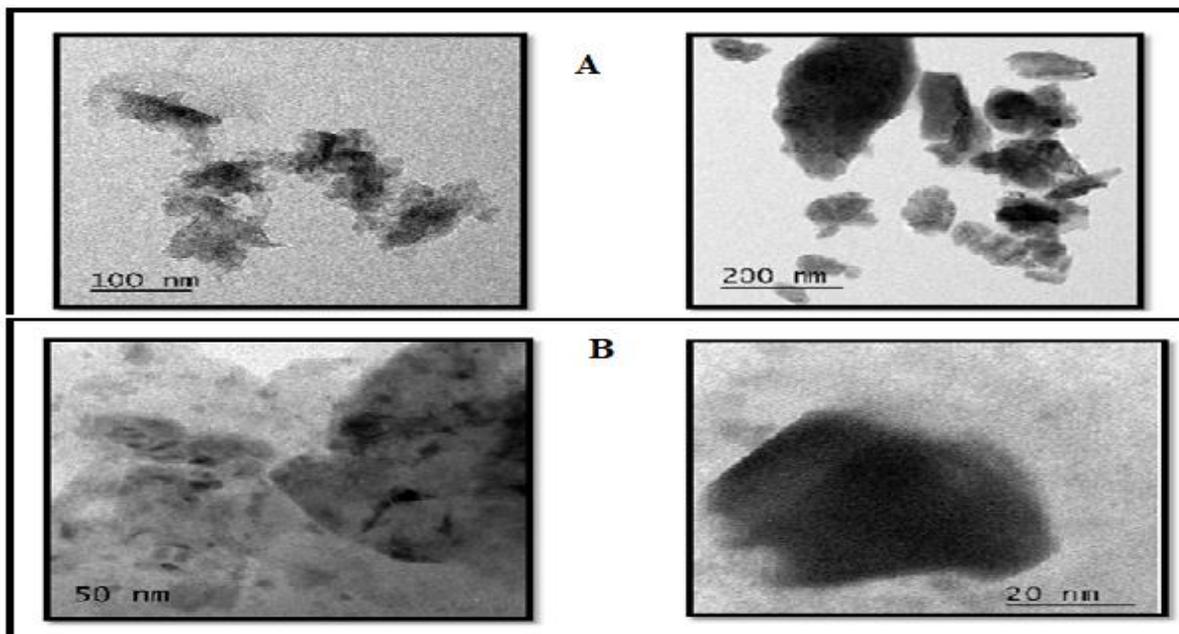
Figure 8 TEM images of (A) pure drug (B) BNCGGPRX.

Particle size analysis

From the particle size analysis data it was observed that the average particle size distribution of BNCGGPRX is 267.21 nm and when the data of particle size compared with TEM images, the particle size of drug may found between 20-100 nm and remaining particle size of 100-200 nm will be of polymer. Therefore we can say that the found particle size of drug is in the range of nanoparticles. Particle size distribution of BNCGGPRX shown in figure 9.
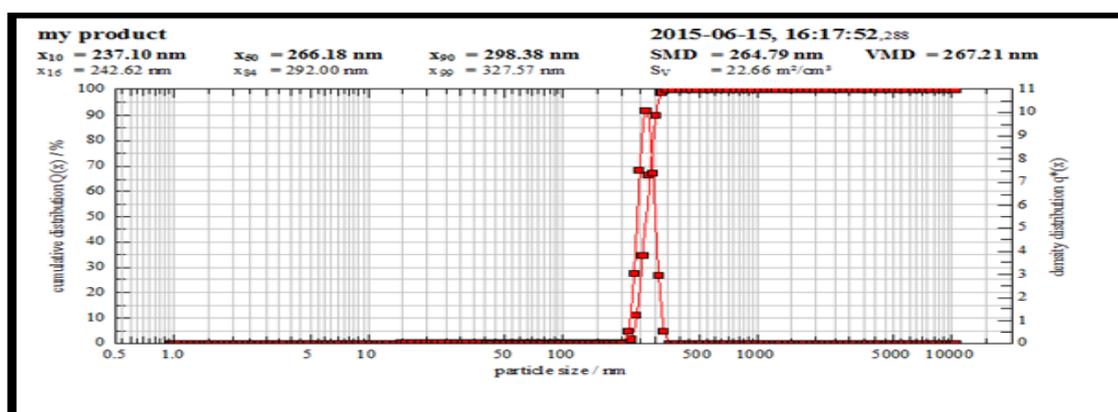
Figure 9 Particle size distribution of BNCGGPRX

EVALUATION OF IMMEDIATE RELEASE TABLET

Pre compression evaluation

The angle of repose, Carr's index and hausner's ratio of all formulation are calculated. Results of evaluations of formulation mixtures are shown in table 3. From results of preformulation and post formulation study, it can be concluded that, prepared formulation mixture has excellent flow properties, good Carr's index and Hausner's ratio. Mixture can be easily compressible into tablet and does not show any type of flow problem.

Table 3 Pre compression evaluation of tablet formulation mixture

Sr. No	Formulation	Angle of repose	Carr's index	Hausner's ratio
1	F1	31.79 ± 1.64	10.61 ± 0.41	1.132 ± 0.017
2	F2	30.54 ± 1.72	11.78 ± 1.92	1.132 ± 0.007
3	F3	30.32 ± 1.47	10.35 ± 1.03	1.115 ± 0.020
4	F4	30.24 ± 2.24	11.70 ± 1.30	1.126 ± 0.012
5	Pure	37.41 ± 1.70	15.28 ± 1.21	1.180 ± 0.017

Data are means $\pm$ SD, n=3

The prepared powder blend for formulation of batches shows acceptable flow ability according to the angle of repose measurement but pure drug powder shows high angle of repose due to cohesive nature. Carr's index and Hausner's ratio of powder blend was found to be acceptable flow property limitation.

Post compression evaluation

The prepared formulation was subjected to various test for post compression evaluation such as weight variation, hardness, friability, content uniformity of prepared tablets, and disintegration all results are within the limit given in the USP 30. Shown in table 4.

Table 4 Post compression evaluation of tablet

Sr. No	Formulation	Weight variation(mg)	%friability	Hardness(Kg/cm^2)	Drug content uniformity(%)	Disintegration time (S)
1.	F1	202.0 ± 1.48	0.78%	3.23 ± 0.18	98.39	61 ± 1.66
2.	F2	201.3 ± 1.92	0.63%	3.56 ± 0.13	100.95	56 ± 2.18
3.	F3	203.4 ± 1.21	0.59%	2.92 ± 0.23	98.52	44 ± 2.06
4.	F4	203.7 ± 1.52	0.61%	3.62 ± 0.16	97.50	46 ± 2.33

Data are means $\pm$ SD, n=3

Tablets obtained from various batches were of uniform weight due to uniform die fill with acceptable variation as per standard limit of weight variation test. All the prepared formulation batches shows good hardness ranging from 2.92 ± 0.23 to 3.62 ± 0.16 and which are within the acceptable limit. The percentage friability of tablet and percentage drug content of all the tablet formulations were within acceptable limit. Disintegration time of all tablet formulations were ranging from 44 ± 2.06 to 61 ± 1.66 and found to be acceptable limit.

In - vitro dissolution study of tablets

From the result of preformulation and post formulation study it can be observed that the formulation F3 of piroxicam shows best result and they are optimized. Shown in figure 10.
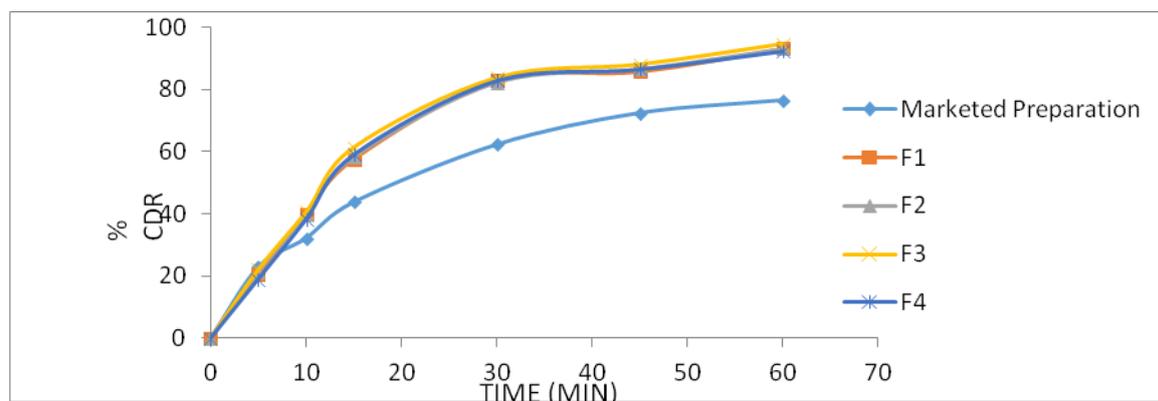
Figure 10 In-vitro dissolution test of Piroxicam tablets

Stability studies

Optimized formulation was subjected to stability studies. Various parameters such as disintegration time, drug content and in-vitro drug release were measured after 0, 30, 60, and 90 days of stability. Results of stability study are shown in table no 9.20. Result of stability study shows (Table 5), there is no significant change in disintegration time, drug content and in-vitro drug release after stress condition during stability study. From stability study it can be conclude that prepared formulation is stable and not much affected by stress condition.

Table 5 Stability study of optimized formulation of piroxicam (F3)

Time (Days)	Disintegration time (min)	% Drug content	% In-vitro drug Release
0	44 ± 1.42	98.37	94.24 ± 1.17
30	43 ± 1.08	98.81	93.49 ± 1.24
60	44 ± 0.22	97.59	94.72 ± 1.56
90	44 ± 1.62	98.12	93.36 ± 1.36

Data are means ± SD, n=3

CONCLUSION

In the present study Gutty gum, Acacia gum and Guar gum was employed in the preparation of microwave generated Bionanocomposite for the solubility and dissolution enhancement. The BNCGG shows best results regarding solubility and dissolution enhancement and hence selected for the formulation of tablets. From the FTIR, DSC, XRD, SEM and TEM characterization it can be concluded that drug had been converted to nanocrystals in the composite and this was responsible for the solubility enhancement. Many factors contributed to faster release rate such as decrease in particle size and crystallinity of the drug. Characterization also helps in identification of drug and polymers and to confirm that there were no interaction between drug and polymer. The in-vitro evaluation of optimized formulation confirmed the use of BNCs for increase in solubility and dissolution of drug using natural polymer. From the overall study of evaluation results we can conclude that

microwave assisted synthesized Bionanocomposite of piroxicam shows enhancement the solubility and dissolution.

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