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Research Article

FTIR AND RAMAN SPECTROSCOPIC INVESTIGATIONS OF A CONTROLLED RELEASE POLYMERIC SUSPENSION

SUBHASHREE SAHOO[A]*, CHANDRA KANTI CHAKRABORTI[A], PRADIPTA KUMAR BEHERA[B], SUBASH CHANDRA MISHRA[C]

[a]Department of Pharmaceutics, Kanak Manjari Institute of Pharmaceutical Sciences, Rourkela 769015, [b]School of Chemistry, Sambalpur University, Jyoti Bihar 768019, [c]Metallurgical and Materials Engg. Dept., National Institute of Technology, Rourkela 769008, Orissa, India. Email: subha77t@yahoo.co.in

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ABSTRACT

Very few formulations are available, at present, from which the drug is absorbed uniformly, so that safe and effective blood level of Norfloxacin could be maintained for a prolonged period. Considering this limitation, a controlled release mucoadhesive suspension has been prepared for the study by ultrasonication method, using mucoadhesive Carbopol940 polymer. The chemical interaction between Norfloxacin and polymer in formulation has been studied by FTIR and Raman Spectroscopy. From the spectral interpretation, it has been found that in formulation, the carboxylic groups of Norfloxacin and hydroxyl groups of Carbopol940 undergo chemical interaction leading to esterification and hydrogen bonding. The formation of micellies due to esterification and hydrogen bonding causes more drug entrapment and a stable formulation. As a result of which the formulation of Norfloxacin gives better controlled release and mucoadhesive action in the gastrointestinal tract. Hence, Carbopol940 could be considered as an effective carrier for Norfloxacin.

Keywords: Norfloxacin, C940, FTIR, Raman Spectroscopy and Mucoadhesive formulation

INTRODUCTION

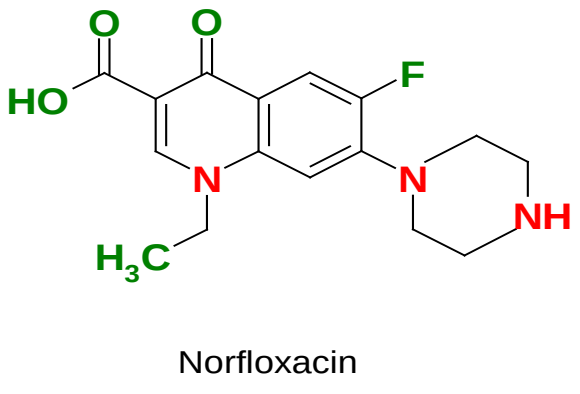
Norfloxacin (Norflox), 1-ethyl-6-fluoro-1,4-dihydro-4-oxo-7-(1-piperazinyl)-3-quinolone carboxylic acid, is a second generation fluoroquinolone (Fig 1). It inhibits the enzyme deoxyribonucleic acid (DNA) gyrase preventing DNA and protein synthesis. It requires multiple administration of drug, leading to fluctuation in plasma concentration of the drug[1].

There is a demand for a dosage form that will provide a drug at a sustained and constant level in solution, in the basic pH conditions of the intestinal lumen over the full dosage period. By achieving constant blood level, drug benefit is maximized while its potential toxicity is minimized[2]. There are several means of achieving sustained release, such as by suspending the drug in the suspension (at a concentration exceeding the solubility), by formulating the drug as micro- or nanospheres, by distributing the drugs to the liposome or surfactant aggregates or by utilizing interaction between the drug and the polymer[3].

Carbopol polymers form hydrogel that change their swelling behaviour upon exposure to an external stimulus such as change in pH[4,5], temperature[6], light, or electric field, and are known as "environmentally responsive polymers" or "smart gels" [7,8]. They have recently attracted considerable interest in the field of drug delivery as a means of providing an on-off release by shrinking and swelling in response to the change in pH[9-12]. In stomach, Carbopol polymer forms hydrogen bond with the drug and also with the polysaccharides or proteins of mucosa, which is probably the major mechanism for bioadhesion. In addition, under alkaline condition of the intestine, Carbopol gels are very highly swollen[13]. Carbopol polymer in mucoadhesive formulation may provide a gastric retention system by swelling in the stomach and inducing a pseudofed state, thereby reducing peristaltic contraction. This phenomenon is dependent on viscosity - the higher the viscosity, the lower the contraction [14]. In the present study design, Carbopol940 (C940) is used as a polymer, which consists of chains of polyacrylic acid[15] (Fig 2).

The hydrophilic polymers may form a complex with the low solubility drug like Norfloxacin. Because it is known that the solubility is the crucial factor for drug effectiveness, independence of the route of administration[16].

While the functional groups of the molecules can be determined by FTIR analysis, the backbone structures and symmetric bonds of molecules can be checked by Raman spectroscopy. Although it is known that Raman and FTIR are complementary vibrational spectroscopic techniques, there are band intensity differences between the two techniques. Therefore, to obtain more information in detail about chemical interaction between Norfloxacin and C940, both FTIR and Raman analyses were carried out[17,18].



Norfloxacin

Fig. 1: Structure of Norfloxacin

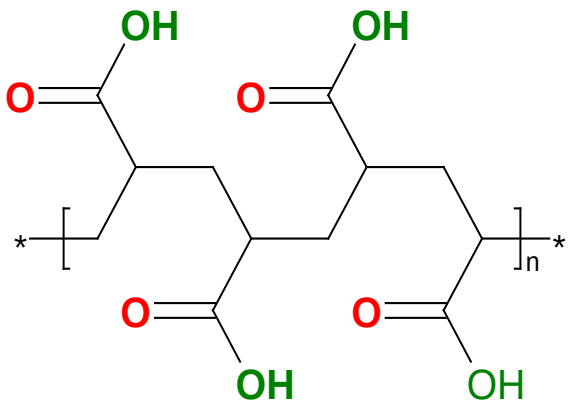


Fig. 2: Structure of Carbopol Polymer (Polyacrylic acid)

MATERIALS AND METHODS

The following materials were used: Norfloxacin was obtained from Dr. Reddy's Lab, Hyderabad, India, as a gift sample. C940, Pluronic F 68 and Soya lecithin were purchased from Himedia Laboratories Pvt. Ltd., India. Glycerol, Methyl praraben sodium, Propyl paraben sodium, Sorbitol solution I.P. and Sucrose were supplied by Cosmo Chem. Laboratory, Pune, India. Ultra pure water was obtained from a Millipore Milli-Q UV water filtration system.

Preparation of Formulation-

1. Praparation of Bulk A

In a beaker 6 ml water was taken and heated up to 80° C. Sucrose (10 gm) was added under continuous stirring. The temperature was monitored in such a way so that it should not fall below 70° C, till the sucrose was completely dissolved. The prepared syrup was cooled properly at room temperature and kept overnight. Syrup was filtered using 120 mesh nylon cloth.

2. Praparation of Bulk B

Five millilitre of Ultra pure water was taken in a beaker to which 1.8 ml of sorbitol solution and 0.2 ml glycerin were added. The mixture was stirred properly. To this solution, pluronic F 68 (5%), soya lecithin (1%) and C940 (5%) in w/w of drug were added with continuous stirring.

3. Preparation of Mucoadhesive Suspension and Ultrasonication

Five millilitre of water was taken in another beaker to which 500 mg of Norflox was added. To the drug suspension, the bulk B and bulk A were added with continuous stirring. Methyl paraben sodium (0.015%w/v) and Propyl paraben sodium (0.08%w/v) were added as preservatives. The volume was made up to 25 ml by Ultra pure water. The pH was adjusted to 5.5. Homogenization was carried out for at least 20 min by ULTRASONIC HOMOZENIZER LABSONIC^{R} M (SARTORIUS), having operating frequency 30 KHZ and line voltage 230 V/50 HZ, using the probe made up of Titanium of diameter 7 mm and length 80 mm. The setting knob "cycle" was adjusted to 0.8, indicating sound was emitted for 0.8 s and paused for 0.2 s. In this manner, we could expose our sample with 100% amplitude, while reducing the heating effect to 80%. This LABSONIC^{R}M generates longitudinal mechanical vibrations with a frequency of 30,000 oscillations / s (30 KHZ). The probes bolted to the sound transducer were made of high-strength Titanium alloys, built as λ /2 oscillators. It amplified the vertical oscillation, and transferred the ultrasonic energy via its front surface with extremely high power density into the sample that was to be subjected to ultrasonic waves. In our study, stress applied was sound wave and in addition, mild rise in temperature of the sample occurred during ultrasonication which helped in the homogenization of the suspension. The sample was then divided into two parts –one part was for FTIR analysis and the other part was used for Raman spectroscopy.

Fourier Transform Infrared Spectroscopic Analysis-

After ultrasonication, the polymeric suspension was sprayed on to an aluminum slip with the aid of an atomizer. The fine droplets were dried overnight at room temperature and the solid samples were then collected and powdered. This powder sample was used for FTIR analysis. The Fourier transform infrared analysis was conducted to verify the possibility of interaction of chemical bonds between drug and polymer. FTIR analysis was performed by FTIR Spectrophotometer interfaced with infrared (IR) microscope operated in reflectance mode. The microscope was equipped with a video camera, a liquid Nitrogen-cooled Mercury Cadmium Telluride (MCT) detector and a computer controlled translation stage, programmable in the x and y directions. Solid powder samples were oven dried at around 30°C, finely crushed, mixed with potassium bromide (1:100 ratio by weight) and pressed at 15000 psig (using a Carver Laboratory Press, Model C, Fred S. carver Inc., WIS 53051) to form disc. The detector was purged carefully using clean dry nitrogen gas to increase the signal level and reduce moisture. The spectra were collected in the 400 cm^{-1} to 4000 cm^{-1} region with 8 cm^{-1} resolution, 60 scans and beam spot size of 10 µm-100 µm[19-21]. The FTIR imaging in the present investigation was carried out using a Perkin Elmer Spectrum RX.

Raman Spectroscopic Analysis-

The Raman system R-3000 instrument (Raman systems INC.USA), a low resolution potable Raman Spectrometer using a 785 nm solid state diode laser, was adjusted to deliver 250 mw to the sample having spectral resolution 10 cm^{-1} and 12 v dc/5A power supplies and USB connectivity. The solid powder samples i.e., both pure drug and polymers were enclosed in plastic poly bags and tested directly. For our study, the fibre optic sampling probe was directly dipped into the formulation (prepared as per the above-mentioned procedure) to collect the spectra at room temperature. The interference of the outside light was also prohibited to prevent photon shot noise. The spectra were collected over the wave number range from 140 to 2400 cm^{-1}.

RESULTS

The infrared spectra are recorded on Fourier Transform Spectrometer in the mid –infrared region (MIR) within the range (400-4500 cm^{-1})[22]. Due to the complex interaction of atoms within the molecule, IR absorption of the functional groups may vary over a wide range. However, it has been found that many functional groups give characteristic IR absorption at specific narrow frequency range. Multiple functional groups may absorb at one particular frequency range but a functional group often gives rise to several characteristic absorptions. Thus, the spectral interpretations should not be confined to one or two bands only; actually, the whole spectrum should be examined.

While the FTIR bands at 4000-1300 cm^{-1} represented functional group region, the appearance of strong absorption bands in the region of 4000 to 2500 cm^{-1} was due to stretching vibrations between hydrogen and some other atoms with a mass of 19 or less. The O-H and N-H stretching frequencies were in the 3700 to 2500 cm^{-1} region with various intensities. Hydrogen bonding has a significant influence on the peak shape and intensities, generally causing peak broadening and shifts in absorption to lower frequencies. The C-H stretching vibration occurred in the region of 3300 to 2800 cm^{-1} [19,20].

In FTIR spectra of Norfloxacin, one prominent characteristic peak was found between 3550 and 3500 cm^{-1}, which was assigned to stretching vibration of OH group and intermolecular hydrogen bonding by single bridge. A band at 3500 to 3300 cm^{-1} suggested the NH stretching vibration of the imino-moiety of piperazinyl groups. The peak at 2750-2700 cm^{-1} indicated the presence ethyl group. The band at 2500 cm^{-1} was due to the υOH group of the carboxylic acid. The peak at 1700 cm^{-1} represented the carbonyl C=O stretching i.e., $\upsilon_{C=O}$. The band at 1650 to 1600 cm^{-1} was assigned to υN-H bending vibration of quinolones. The peaks at 1500 to 1450 cm^{-1} represented υ_{O-C-O} of acids and at 1300 to 1250 cm^{-1} suggested bending vibration of O-H group, which indicated the presence of carboxylic acid. In addition, a strong absorption band between 1050 and 1000 cm^{-1} was assigned to C-F group. The peak in the region 950-900 cm^{-1} suggested the δNH bending vibration of amines. The band at 800 cm^{-1} was due to the meta distribution of the aromatic protons[20,23-25] (Fig 3 and Table 1).

In case of C940, the FTIR spectra having peak between 3000 and 2950 cm^{-1} represented OH stretching vibration, i.e., υ_{O-H} and intramolecular hydrogen bonding (Fig 4). The prominent band between 1750 and 1700 cm^{-1} was assigned to carbonyl C=O stretching vibration i.e., $\upsilon_{C=O}$. While the peak at 1450 to 1400 cm^{-1} was for υ_{C-O} / δ_{O-H}, the band at 1250 to 1200 cm^{-1} was due to υ_{C-O-C} of acrylates [20,22]. The band between 850 and 800 cm^{-1} was for out of plane bending of =C-H i.e., $\delta_{=C-H}$ [19,22] (Table 2).

In the FTIR spectra of formulation containing both Norflox and C940, the prominent band, found between 3550 and 3500 cm^{-1}, was assigned to υ_{O-H} and polymeric hydrogen bonding (Fig 5). The peak at 2600-2500 cm^{-1} represented the υ_{O-H} of carboxylic acid i.e., strong intermolecular hydrogen bonding. The band from 1650 to 1600 cm^{-1} was assigned to $\upsilon_{C=O}$ i.e., carbonyl stretching vibration. A prominent peak at 1500 - 1450 cm^{-1}(w) was for υ_{C-O} / δ_{O-H}. The band from 1300 to 1250 cm^{-1} was due to υ_{C-O-C} of acrylates. The peak between 1100 and 1000 cm^{-1} represented υ_{C-F} groups. The band at 800 cm^{-1} indicated

the meta distribution of δ_{Ar-H} group [19, 20,22] (Table 3). Figure 6 indicates comparative FTIR peaks of the pure drug, polymer and formulation.

By Raman spectroscopy of Norfloxacin, the prominent Raman shifts have been observed at 485.6, 872.7, 1418.5 and 1655.1 cm^{-1} (Fig 7). The Raman shifts at 485.6 cm^{-1} indicated strong bending vibration of C-C of the aliphatic chain and C-N stretching vibration of piperazinyl group [26-28]. The band at 872.7 cm^{-1} represented the symmetric stretching vibration of C-F group[30]. The peak at 1418.5 cm^{-1} was due to symmetric stretching vibration of O-C-O group of carboxylic acid and methylene deformation mode of the piperazinyl group[30]. A band at 1655.1 cm^{-1} was for symmetric stretching of the carbonyl group $\upsilon_{C=O}$ of the pyridone moiety, the stretching vibration of (C-C) aromatic ring chain. In addition, it (peak at 1655.1 cm^{-1}) also indicated the $N^{+}H_2$ scissoring of piperzinyl group[26,30 - 33] (Table 4a).

The characteristic prominent Raman bands for C940 were observed at 523.9, 876.8 and 1366.5 cm^{-1} (Fig 8). The bending vibration of C-C-O group was indicated by the Raman shift at 523.9 cm^{-1}. The band at 876.8 cm^{-1} was due to stretching vibration of C-O-C for acrylates and carboxylic acid. The Raman band at 1366.5 cm^{-1} was assigned to symmetric vibration of O-C-O of acids[26] (Table 4b).

In the formulation containing both Norflox and C940, the Raman peak at 338.8 cm^{-1} represented bending vibration of δCC of aliphatic chain (Fig 9). The band at 900-850 cm^{-1} was assigned to symmetric stretching vibration of both C-F group and C-O-C group for acrylates and esters. The peak at 1100-1050 cm^{-1} represented stretching vibration of carbonyl group. The band at 1400-1350 cm^{-1} suggested for symmetric stretching vibration of O-C-O group. The peak at 1550 cm^{-1} was due to asymmetric vibration of O-C-O group.

The band at 1850 to 1700 cm^{-1} was the characteristic of stretching vibration of carbonyl group of esters[26,33] (Table 4c). Figure 10 indicates comparative Raman shifts of the pure drug, polymer and formulation.

Table 1: Prominent FTIR peaks of Norfloxacin

Peaks(cm-1)	Groups	Peak assignment
3550-3500	Hydroxyl group	Intermolecular H -bonding by single bridge
3500-3300	Imino-moiety of Piperazinyl groups	NH stretching vibration
3000-2950	Aromatic,cyclic enes	υ=CH & Ar-H
2750-2700	Ethyl group	υCH_2
2500	Acid group	υOH group
1700	Carbonyl of acids	υC=O stretching vibration
1650-1600	Quinolones	υN-H bending vibration
1500-1450	O-C-O group of acid	υ_s stretching vibration of O-C-O group
1300-1250	Hydroxyl group	δO-H bending vibration
1050-1000	C-F groups	υC-F
950-900	Amines	δNH bending vibration
800	Aromatic m – distribution	δAr-H

Fig. 3: FTIR peaks of Norfloxacin

Table 2: Prominent FTIR peaks of C940

Peaks(cm-1)	Groups	Peak assignment
3000-2950	Hydroxyl group	O-H stretching vibration, intramolecular H-bonded
1750-1700	C=O group of acids	$\upsilon_{C=O}$ stretching vibration
1450-1400	Carbonyl group of acids	υ_{C-O}
1250-1200	Acrylates	C-O-C stretching vibration
850-800	Aromatics & enes	=C-H out of plane bending vibration

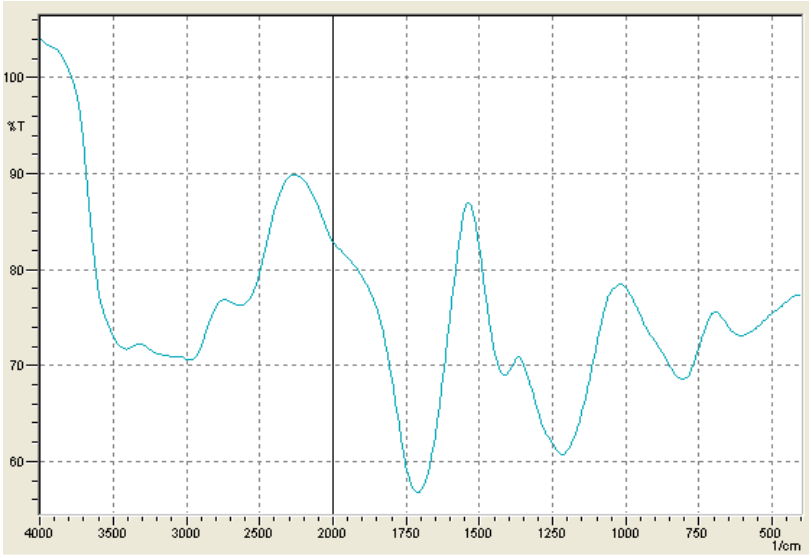


Fig. 4: FTIR peaks of Carbopol940

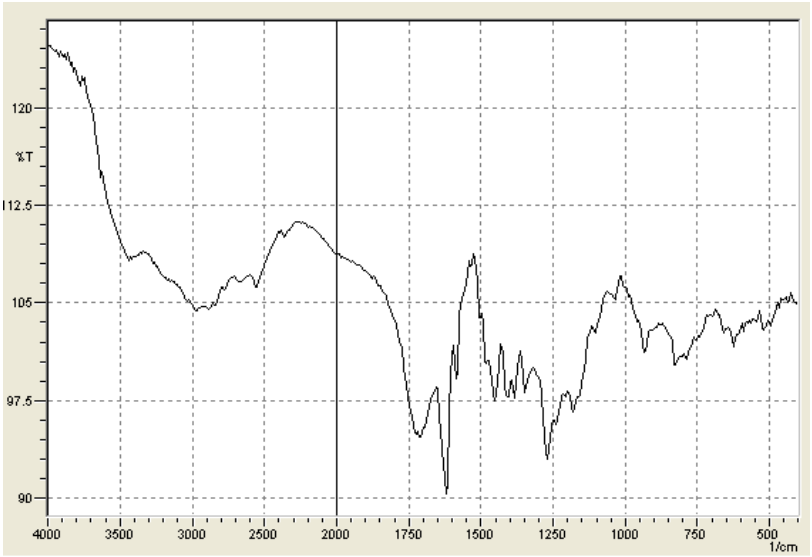


Fig. 5: FTIR peaks of Norfloxacin Mucoadhesive Formulation

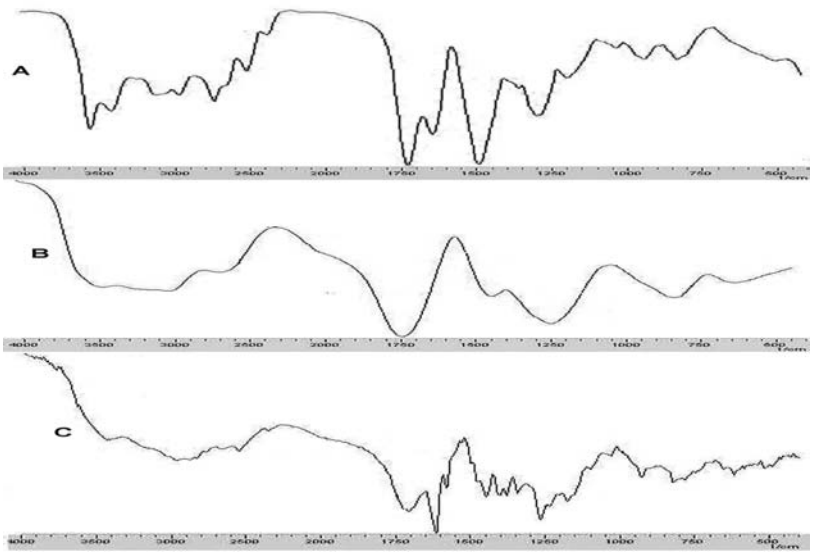


Fig. 6: Comparative FTIR peaks of Norflox (A), C940 (B) and Formulation (C)

Table 3: Prominent FTIR Peaks of Mucoadhesive Formulation

PEAKS(cm-1)	GROUPS	PEAK ASSIGNMENT
3550-3500	Hydroxyl group	Polymeric H -bonding
2600-2500	Hydroxyl group of carboxylic acid	Strong intermolecular H- bonding
1650-1600	O-C-O group of acid	υ_{as} stretching vibration of O-C-O group
1500-1450	O-C-O group of acid	υ_{s} stretching vibration of O-C-O group
1300-1250	Acrylates & esters	C-O-C stretching vibration
1100-1000	C-F groups	υC-F
800	Aromatic m – distribution	δAr-H

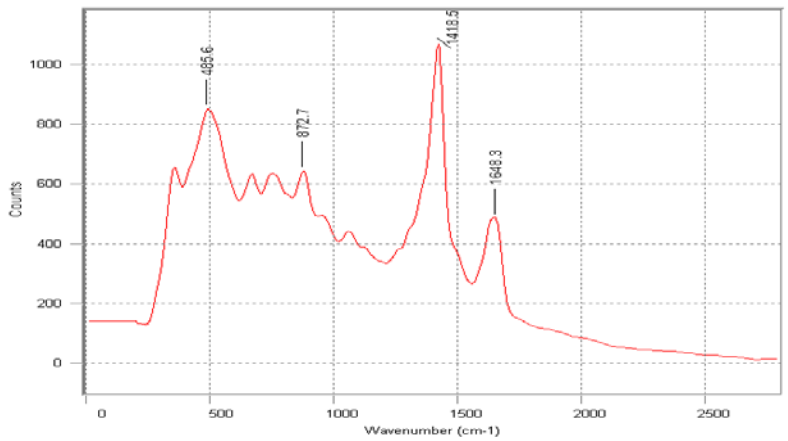


Fig. 7: Raman Shifts of Norfloxacin

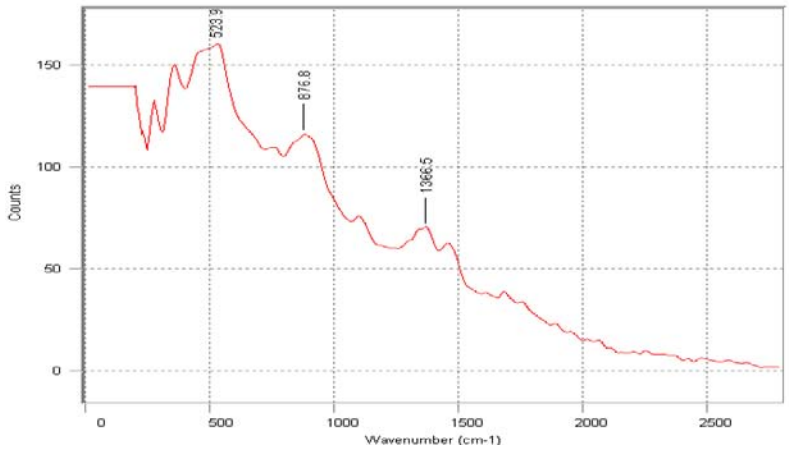


Fig. 8: Raman Shifts of Carbopol940

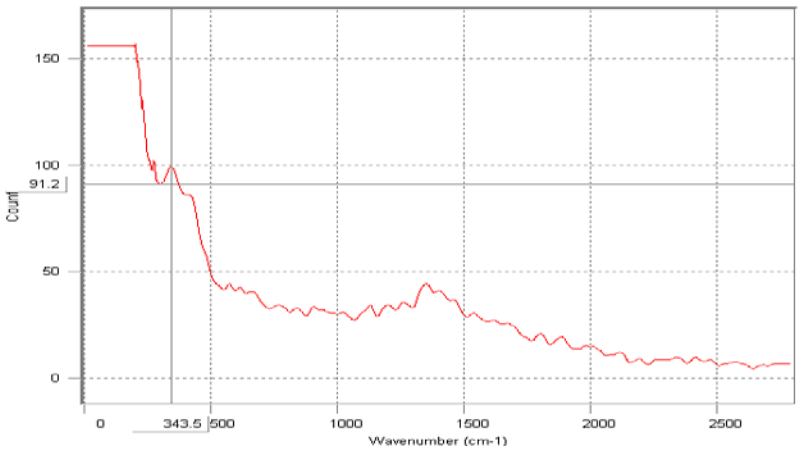


Fig. 9: Raman Shifts of Norfloxacin Mucoadhesive Formulation

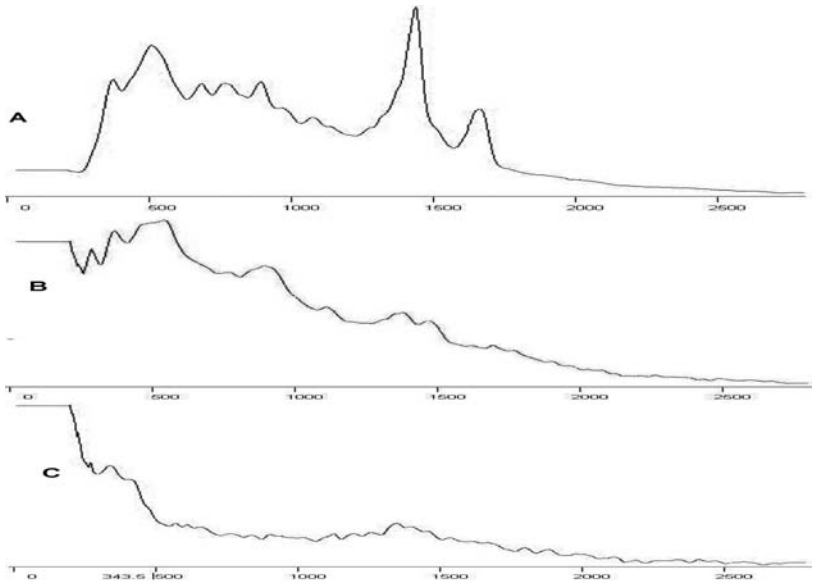


Fig. 10: Comparative Raman Shifts of Norflox (A), C940 (B) and Formulation (C)

Table 4: Raman Shifts of pure Drug, Polymer and Formulation

a) Prominent Raman Shifts of Norfloxacin	
Raman Shifts(cm^{-1})	**Functional Groups / Vibrations**
485.6	Strong $\delta_{(CC)}$ aliphatic chain and C-N stretching vibration
872.7	Symmetric vibration of C-F bond
1418.5	$\upsilon_{S\ O\text{-}C\text{-}O}$ and methylene deformation of the piperazinyl group
1655.1	υ_s of C=O group of pyridone moiety and N^+H_2 scissoring of piperzinyl group
b) Prominent Raman Shifts of C940	
Raman Shifts(cm^{-1})	**Functional Groups / Vibrations**
450-300	Strong $\delta_{(CC)}$ aliphatic chain
523.9	C-C-O bending vibration
876.8	$\upsilon_{(C\text{-}O\text{-}C)}$ of acrylates
1366.5	$\delta_{(CH3)}$ medium
c) Prominent Raman Shifts of Norfloxacin Mucoadhesive Formulation	
Raman Shifts(cm^{-1})	**Functional Groups / Vibrations**
338.8	δ(CC) aliphatic chain
900-800	Symmetric stretching vibration of both C-F group C-O-C group for acrylates and esters
1100-1050	Stretching vibration of CO
1400-1350	υ_sO-C-O
1550	υ_{as}O-C-O
1850-1700	υC=O medium

DISCUSSION

When FTIR radiation falls on a molecule, it may be absorbed, reflected or transmitted. Absorption leads to the FTIR spectrum, while reflection leads to scattering which is utilized in Raman Spectroscopy[19]. In addition, Infra red (IR) absorption of the functional groups may vary over a wide range. However, it has been found that many functional groups give characteristics IR absorption at specific narrow frequency range[19,20].

Infra red (IR) absorption of the functional groups may vary over a wide range. However, it has been found that many functional groups give characteristics IR absorption at specific narrow frequency range[19-21].

In case of FTIR spectra of Norflox, prominent peaks for $\upsilon_{C\text{-}O}$ / $\delta_{O\text{-}H}$ and $\upsilon_{C=O}$ indicated the presence of –CO-, -CHO and -COOH groups (Fig 3). The presence of above groups can be confirmed by fermi resonance bands for –CHO, $\upsilon_{C\text{-}O\text{-}C}$ bands for esters and absence of these two for ketones. This suggested the existence of –COOH group in Norflox molecule (Table 1).

Another probability of intermolecular hydrogen bonding may be due to prominent FTIR peaks between 3550 and 3500 cm^{-1}. The band at 3500-3300 cm^{-1} indicated the presence of piperazinyl group. The presence of ethyl group was confirmed by the appearance of a sharp peak at 2750-2700 cm^{-1} [20,34,35]. The band at 1650-1600 cm^{-1} was due to the quinolone moiety of Norfloxacin. The bending vibration of O-H group showed medium to strong band in the region around 1300-1250 cm^{-1}, which confirmed the presence of COOH group. Here, the FTIR peak at 950-800 cm^{-1} suggested the probability of bending of NH group. The band at 1050-1000 cm^{-1} indicated the presence of C-F group which takes a major role in its antimicrobial activity (Table 1) [19,20,23].

In case of FTIR spectra of Carbopol940, there were prominent peaks for intramolecular hydrogen bonding, υ_{OH} stretching vibration, carbonylic C=O and C-O stretching vibration and stretching vibration for the C-O-C, which confirmed the presence of acrylates (Fig 4). The peak for out of plane bending vibration of =C-H was found between 850 and 800 cm^{-1} (Table 2).

While comparing the FTIR spectra among the pure Norflox and C940, and the formulation containing both Norflox and C940, it is clear that the band position of C=O group has been affected by esterification and conjugation involving C=O group. Here, the stretching vibration of C=O in pure Norflox was found at 1700 cm^{-1},

which was lowered to 1650-1600 cm^{-1} in this formulation might be due to formation of β-ketoesters (Fig 6). The FTIR peaks assigned to υ_{C-O} and υ_{C-O-C} represented acrylates and esters, which confirmed the esterification between polymeric OH group and –COOH group of Norflox. The stretching vibration of C-F group remained nearly unaltered. The another probability of interaction is hydrogen bonding i.e., intermolecular hydrogen bonding due to prominent FTIR peaks between 3550 and 3500 cm^{-1}, and 2600 and 2500 cm^{-1} represented polymeric O-H...O-H…O-H and strong carboxylic OH hydrogen bonding respectively. The hydrogen bonded -OH stretching vibration occurred over a wide range, 3550-2500 cm^{-1}. The bending vibration of O-H group showed medium to strong bands in the region around 1300-1250 cm^{-1}. The FTIR peak at 800 cm^{-1} suggested the probability of out of plane bending of –ene bond and m-substitution of δ_{Ar-H} hydrogen atom (Table 3) [19,20,22].

The C=O group of drug lowers the stretching vibration of C=O frequency indicating deprotonation and probably interaction of the said carboxylic C=O moiety with the polymer. However, a definitive conclusion about the keto group in the bonding to the polymer could be deduced because the corresponding band found from 1650 to 1600 cm^{-1} was due to probability of formation of β-ketoesters[29]. From the above data, it can be inferred that the carboxylic group of Norflox undergoes the interaction with the polymer, as would be expected chemically. Thus, the nitrogen atoms aren't likely to be involved in binding or the interaction. The nitrogen atom of the quinolone ring, 1-ortho to fluorine, is less electron rich due to electron deficient fluoroquinolone ring. In addition, ethyl and piperazinyl groups sterically hinder the reaction. The possibility of involvement of imino moiety of the piperazinyl group is also less prominent due to intense OH stretching vibration. The bands in the region 3550-2500 cm^{-1} could be assigned to the asymmetric and symmetric stretching vibrations of the OH groups of the inner and outer sphere of polymer. The shift in the characteristic bands of the FTIR spectra suggests change in their intensity, leading to the appearance of several absorbance bands of the asymmetric and symmetric stretching vibrations and overtone of the deformation vibrations. This indicates the confirmation of the hydrogen bonding[36]. By comparing the FTIR spectra among the pure drug, Carbopol polymer (C940) and the formulation containing both drug and polymer, the FTIR peak of Norflox at 1700 cm^{-1} was not detected in the mucoadhesive system probably due to interaction with polymer. The missing peak was replaced by two very strong characteristic bands in the range of 1650-1600 cm^{-1} and at 1500-1450 cm^{-1}, which were assigned to $\upsilon_{(O-C-O)}$ asymmetric and symmetric stretching vibrations, respectively[20,37]. The difference Δ $[\upsilon_{(CO2)asym} - \upsilon_{(CO2)sym}]$ is a useful characteristic for determining the involvement of the carboxylic group of Norflox. The Δ value for the interaction falls in the range of 183 - 250 cm^{-1} indicates the deprotonation of the carboxylic acid group and interaction between drug and polymer[32] (Table 1- 3).

In case of Raman spectra of Norflox, band at 485.6 cm^{-1} was assigned to the stretching vibration of ethyl group. The peak at 872.7 cm^{-1} represented stretching vibration of C-F group. The presence of carboxylic acid group was confirmed by υ_{O-C-O} and $\upsilon_{C=O}$ groups vibration at 1418.5 cm^{-1} and 1655.1 cm^{-1}, respectively (Table 4a).

By comparing the Raman spectra of pure drug with the drug incorporated in the Carbopol suspension, the peak at 1418.5 cm^{-1}, assigned to the $\upsilon_{s\ O-C-O}$, is not prominent. Both symmetric and asymmetric stretching vibrations of O-C-O group are found in suspension containing C940. The Raman peak for stretching vibration of C=O is prominent in the suspension. From this it is clear that there is esterification reaction between Norflox and Carbopol polymer (Table 4). The results of both FTIR and Raman spectra indicate that both the spectra show prominent peaks for the stretching vibration of O-C-O and C=O groups, which prove the formation of the esters between the drug and polymer. Moreover, both the intermolecular and polymeric hydrogen bonding are also prominent from the FTIR spectra of the formulation.

On the basis of above interpretation, it may be concluded that by preparing mucoadhesive suspension of Norfloxacin with Carbopol polymer (C940) following a novel method of ultrasonication, a very good interaction occurs between the carboxylic group of drug and hydroxyl group of polymer. This leads to esterification and intermolecular hydrogen bonding, by virtue of which a stable formulation would be produced. Moreover, the drug polymer complex may aggregate forming a micelle like structure which can absorb and solubilize more drugs. As a result of which Carbopol940 polymer may function as a useful carrier for Norflox molecule. The main advantage of the present investigation is that higher drug (Norflox) loading would be possible in dosage forms as compared to conventional formulation strategies. Here, Norflox interacts with the polymer monomerically. The release of drug from the formulation system is very slow because the carboxylic group of Norflox interacts with polymeric OH groups. It suggests less active site of the drug is left for the attack by water molecules for the hydration and solubilization, which gives controlled release action. In addition, the free polymeric carboxylic groups form hydrogen bonding with the polysaccharides and proteins of mucosa in the acidic condition of the stomach. On the other hand, mucoadhesive suspension is highly swollen and stiffened in an alkaline condition of the intestine showing a very good mucoadhesive property of the formulation in the gastrointestinal mucosa. This leads to a better bioadhesive and controlled release action. The utility of the present work may be improved if their delivery rate, biodegradation and site-specific targeting of such mucoadhesive suspension would be monitored and controlled.

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