

Original Article

FTIR Spectroscopic Analysis for the Identification and Characterization of Selected Anti-Diabetic Drugs

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Abstract

Fourier Transform Infrared (FTIR) spectroscopy is a widely used analytical technique for the identification and characterization of pharmaceutical compounds. The present study aims to analyze three selected anti-diabetic drugs as Glimepiride, Metformin hydrochloride, and Sitagliptin using FTIR spectroscopy. Spectral analysis was carried out in the range of 4000–650 cm^{-1} . Characteristic absorption peaks corresponding to functional groups such as N–H, C=O, C=N, and S=O were identified and interpreted for each drug. The obtained spectra exhibited distinct molecular fingerprints, confirming the structural integrity and purity of the selected compounds. Comparative evaluation of spectra enabled clear differentiation among the drugs based on their functional group vibrations. The results demonstrate that FTIR spectroscopy is a rapid, reliable, and non-destructive technique for qualitative analysis and identification of anti-diabetic pharmaceutical drugs. This study highlights its significance in routine drug analysis and quality control applications in pharmaceutical industries.

Keywords: FTIR spectroscopy; Anti-diabetic drugs; Glimepiride; Metformin hydrochloride; Sitagliptin; Pharmaceutical analysis.

Introduction

Diabetes mellitus is a long-term metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both. The increasing global prevalence of diabetes has led to extensive use of oral anti-diabetic agents such as Glimepiride, Metformin hydrochloride, and Sitagliptin. These drugs belong to different pharmacological classes and possess distinct chemical structures, necessitating reliable analytical techniques for their identification and quality assessment [1–3]. Among the various analytical techniques, Fourier Transform Infrared (FTIR) spectroscopy has emerged as a powerful and versatile tool in pharmaceutical analysis. FTIR spectroscopy operates on the principle that molecules absorb infrared radiation at frequencies corresponding to the vibrational transitions of their chemical bonds. Each compound produces a unique spectrum that can be considered its molecular fingerprint [4,5]. The technique offers several advantages, including minimal sample preparation, rapid analysis, non-destructive nature, and the ability to identify functional groups with high specificity. It is widely used for drug identification, compatibility studies, and detection of impurities [6, 7]. The objective of the present study is to perform FTIR spectroscopic analysis of selected anti-diabetic drugs and to interpret their characteristic absorption bands for structural confirmation and comparative evaluation. Oral anti-diabetic drugs are often preferred early in type 2 diabetes because they're simpler and less invasive. According to standards suggested by American Diabetes Association, Insulin therapy while essential in many cases of Diabetes Mellitus, but it has some drawbacks compared to oral anti-diabetic tablets, especially for people with Type 2 Diabetes. It requires injections, which can be uncomfortable and less convenient than taking pills. Insulin also carries a higher risk of hypoglycemia (low blood sugar), particularly if doses are not carefully matched with food intake and activity. Additionally, it often leads to weight gain, whereas some oral medications like Metformin are weight-neutral or may aid in weight control. Insulin therapy can also be more expensive due to the need for syringes, pens, or pumps, and it requires proper storage (usually refrigeration), making it less convenient for daily use [8].

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Materials and Methods:

Materials- Pure samples of Glimepiride, Metformin hydrochloride, and Sitagliptin were obtained from pharmaceutical sources.

Instrumentation-FTIR spectra were recorded using a high-resolution Fourier Transform Infrared Spectrophotometer [Agilent technologies-630 ATR] equipped with a Deuterated Triglycine Sulfate (DTGS) detector. The spectral range was set between 4000 and 650 cm^{-1} , with appropriate resolution settings.

Sample Preparation-The inner part of each drug sample was finely powdered using mortal pastel and directly used for the analysis. Approximately 1–2 mg of drug sample was used for the experimentation. The prepared powders were placed in the sample holder for the analysis.

Experimental Procedure-Each prepared sample was scanned under identical conditions. The resulting spectra were analyzed for: Peak positions (wave number, cm^{-1}), Peak intensity, Functional group assignments. Assignments were made using standard IR correlation charts and literature references [9–11].

Results and Discussion:

1. FTIR Analysis of Metformin Hydrochloride :

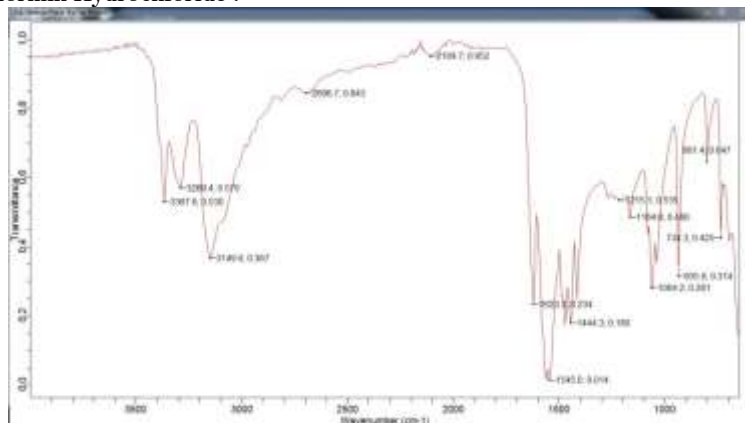


Fig.1. FTIR spectrum of Metformin hydrochloride

Metformin hydrochloride exhibits characteristic peaks corresponding to its biguanide structure. The broad absorption band observed between 3367–3289 cm^{-1} is attributed to N–H stretching vibrations of primary amine groups. The peak at 3149 cm^{-1} indicates secondary amine stretching. A strong absorption at 1623 cm^{-1} corresponds to C=N stretching vibrations, confirming the presence of imine groups. The band at 1545 cm^{-1} is due to N–H bending vibrations. Peaks in the region of 1064–1164 cm^{-1} are assigned to C–N stretching modes. These findings are consistent with reported spectral data and confirm the structural integrity of Metformin hydrochloride [12, 13].

2. FTIR Analysis Of Glimepiride :

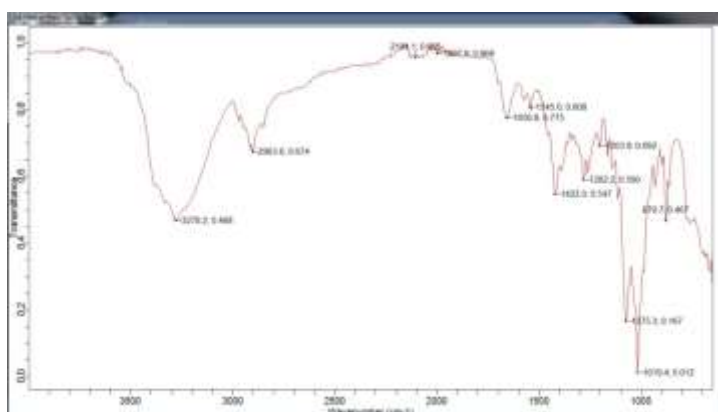


Fig.2. FTIR spectrum of Glimepiride

Glimepiride exhibits a distinct FTIR spectrum due to its sulfonylurea structure. The peak at 3278 cm^{-1} is attributed to N–H stretching vibrations. The absorption at 2903 cm^{-1} corresponds to aliphatic C–H stretching. A prominent peak at 1656 cm^{-1} indicates C=O stretching of the amide group. The band at 1545 cm^{-1} represents N–H bending vibrations. Strong peaks in the region 1203–1282 cm^{-1} correspond to S=O stretching vibrations of the sulfonyl group. These spectral features confirm the presence of sulfonylurea functionality, which is characteristic of Glimepiride [12].

3. FTIR Analysis of Sitagliptin:

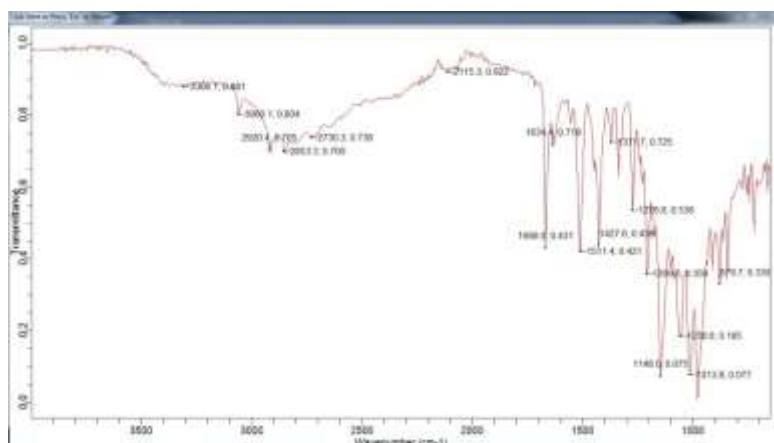


Fig.3.FTIR spectrum of Sitagliptin

The FTIR spectrum of Sitagliptin reveals characteristic functional groups associated with its molecular structure. The peak at 3306 cm^{-1} corresponds to N–H stretching vibrations. The bands at 2920 and 2853 cm^{-1} indicate aliphatic C–H stretching. Strong absorption peaks at 1668 and 1634 cm^{-1} correspond to carbonyl (C=O) stretching vibrations. The band at 1511 cm^{-1} is due to N–H bending, while peaks in the region 1148 – 1276 cm^{-1} are attributed to C–N stretching vibrations. These observations confirm the presence of amide and amine functionalities in Sitagliptin [14].

Comparative Analysis:

A comparative evaluation of the FTIR spectra reveals significant differences among the three drugs:

Metformin hydrochloride shows dominant amine and imine peaks.

Glimepiride exhibits sulfonyl and carbonyl groups.

Sitagliptin shows amide and carbonyl functionalities.

These differences provide a liable basis for identification and differentiation. The absence of extraneous peaks suggests high purity and absence of contamination.

FTIR spectroscopy thus serves as an effective tool for molecular fingerprinting and quality assessment [15,16].

Conclusion

The present study successfully demonstrates the effectiveness of FTIR spectroscopy in the identification and characterization of selected anti-diabetic drugs. Each drug exhibited unique and well-defined spectral features corresponding to its specific functional groups, which enabled clear differentiation and confirmation of their chemical identity. The obtained spectra were consistent with standard reference data, validating the reliability of the technique. The ability of FTIR spectroscopy to generate characteristic molecular fingerprints makes it highly suitable for routine pharmaceutical analysis. The method efficiently detected functional groups such as hydroxyl, carbonyl, amine, and aromatic moieties, which are crucial for structural confirmation of drug compounds. Furthermore, the study highlights the applicability of FTIR spectroscopy in pharmaceutical quality control, where it can be used for drug authentication, detection of impurities, and monitoring of formulation consistency. Insulin therapy has some drawbacks compared to oral anti-diabetic tablets, especially for people with Type 2 Diabetes. Insulin carries a higher risk of hypoglycemia (low blood sugar), particularly if doses are not carefully matched with food intake and activity. Hence oral anti-diabetic drugs are often preferred early in type 2 diabetes. Overall, FTIR spectroscopy emerges as a reliable and versatile tool for qualitative analysis of anti-diabetic drugs, contributing significantly to ensuring drug safety, efficacy, and quality.

Despite its effectiveness, there are several opportunities to expand the scope of this study to Quantitative Analysis, Combination Drug Analysis, Integration with Chemometrics, Detection of Adulteration and Counterfeit Drugs, Comparison with Other Analytical Techniques, Application to Other Drug Categories, Development of Spectral Libraries in which a comprehensive FTIR spectral database for pharmaceutical compounds would support faster identification and standardization.

Declarations:

I hereby declare that the research work presented in this paper is my original work and has been carried out by me under proper guidance. This work has not been submitted elsewhere for the award of any degree, diploma, or certificate.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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