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# Quantitative Determination of Remdesivir in Pure and Pharmaceutical Dosages form by ATR-FTIR Spectroscopic as a Green Method.

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## Abstract

**Background:** A green analytical chemistry method was developed for quantification of remdesivir (CAS-1809249-37-3) in pure and pharmaceutical dosage form. The broad-spectrum antiviral drug Remdesivir (RMD) is injected intravenously. RMD has been licensed or authorized for use in treating COVID-19 in more than 50 countries during the COVID-19 epidemic.

**Objective:** A non-destructive, sensitive, and precise attenuated total reflection-Fourier transform infrared (ATR-FTIR) spectroscopic technique being created and validated for the quick identification of remdesivir in pharmaceutical formulations.

**Methods:** A method used to investigate remdesivir is obtained by measuring the carbonyl group's stretching bands within a spectral range of 1695 to 1740 cm-1. The proposed techniques were fully verified according to ICH recommendations, with linearity ranges of 1.0 to 5.0 mg g-1 for RMD.

**Results:** It was linear over the concentration range of 2.0–10.0 mg with correlation coefficient for method I and method II was found to be 0.9996 & 0.9998 respectively. LOQ and LOD of 0.142 ± 0.09 and 0.079 ± 0.02 mg for method I and 0.198 ± 0.07 and 0.099 ± 0.11 mg, for method II respectively.

**Conclusions:** the analytical strategy has been developed in line with green chemistry, and it was demonstrated that the results obtained were in perfect agreement with destructive techniques.

**Highlights:** ATR-FTIR spectroscopic approach demonstrated great accuracy and precision, is non-destructive, environmentally friendly, less expensive, quick, and conveniently used for pharmaceutical quantitative analysis of RMD formulations.

**Keywords:** Remdesivir, IR spectroscopy, Pharmaceutical matrices, Quantitative analysis, etc.

## 1. Introduction

In many countries, the death rate from chronic HCV (hepatitis C virus) infection has risen due to the ageing of the afflicted population[1–3]. 115 million individuals confirmed positive for HCV, and each year, over 0.5 million of them died as a result of consequences (Liver cancer, cirrhosis and dysfunction)[1–3]. A reform in the management of chronic HCV infection has lately been brought about by direct-acting anti-HCV medications (DAAs), allowing efficient and useful therapy in all instances. As second-generation DAAs medications, Remdesivir (RMD, a hepatitis C virus nucleotide analogue NS5B polymerase inhibitor) received FDA approval. (Figure 1) [4,5]. Remdesivir is an anti-HCV drug that may be given intravenously and has a broad range of genetic coverage[5]. When administered orally to animals, the modified form of remdesivir proved "very effective" in reducing SARS-CoV-2 proliferation and transmission[6]. For the measurement of the investigated directly acting antivirals, all described methods (chromatographic and spectroscopic) were used. When the medications in bulk form and pharmaceutical dosage form are regularly analysed, considerable quantities of organic solvents were used in their analytical techniques[6–9]. Green analytical chemistry (GAC) refers to the application of analytical procedures and strategies that minimise or completely avoid the use or production of potentially harmful substances for the environment or human health [10]. As a result, including green chemistry principles in the design of analytical procedures is critical for cutting reagent and equipment costs while also decreasing their detrimental impact on human life and the environment[10,11]. Exploring novel direct approaches that don't use organic solvents or reagents is one of three ways to lessen the negative environmental impacts of the analytical method[10]. FTIR spectroscopy is a quick analytical method that may yield a plethora of qualitative and quantitative data from solid materials[12]. As a result, In GAC, infrared has a considerable advantage when used for direct descriptive and analytical applications of active pharmaceutical ingredients (API) within their solid-state (liquid-less analytical procedures). Additionally, the ATR-FTIR method has several advantages over other spectrometric and chromatographic methods, such as the capacity to reduce API analysis time consumption without excipient interruption, and also being non-destructive for solid sample materials and operating in an environmentally responsible manner by doing away with the use of chemical reagents in analytical methods[12,13]. Consequently, this study's objective is to develop a non-destructive, quick, precise, cost-effective, and eco-friendly ATR-FTIR spectroscopic approach for the direct measurement of RMD in pure and dosage forms.

## 2. Experimental

### Chemicals and materials

RMD (assigned 99.6% w/w purity) was kindly provided as a gift sample by Mylan Pharma Pvt. Ltd (Bangalore, India). The potassium bromide was purchased from a research lab, in India (Before usage, oven-dry to make sure there is no residual water vapour). The commercially available DESREMTM 100 mg injection of Mylan Pharma Pvt. Ltd (India) and COVIFORTM 100 mg injection of Hetero Lab Pvt. Ltd (India) was bought from the local market for analysis. All of the other chemicals utilised in the development of the technique were AR grades.

### Instrumentation

The ALPHA-IIE FTIR Spectrometer (Bruker) was used for all FTIR measurements, and OPUS-8.0 spectra software (Thermo Electron Corporation, Madison, Wisconsin, United States) has been used for data processing. A210/ D-11 ATR accessory (Handling solids, liquids, powders, paste, viscous samples, etc.) with W303/ D-U ZNSE Optics (for operation in high humidity area). All KBr discs were produced using an Atlas 15T hydraulic press that was manually controlled. The Atlas 15T press apparatus was used to create potassium bromide discs for RMD (Specac Ltd.). In a single reflection arrangement, the ATR sampling device used a diamond internal reflection device contained in a ZnSe support/focusing component. Electronic analytical balance (Shimadzu AUY 220, Japan) has been used all through this project. Additionally, porcelain mortar and pestle and FalconTM 50 mL Conical Tubes have been employed.

### Analytical procedure

In 50-mL FalconTM conical tubes, individually weighed amounts of real RMD powders that fell between the designated ranges were introduced. In the tubes, crystalline potassium bromide powdered was added in a 1: 1 proportion and well mixed with a vortex mixer. At each addition of potassium bromide, the homogenised samples were geometrically reduced and thoroughly mixed by the vortex. The FT-IR spectra of the resulting blends were recorded at 2 cm-1 analytical sensitivity within a mid-IR range (4000–400 cm-1). Under the same optimal circumstances, in combination with potassium bromide, all runs had been documented. By plotting the graph of absorbance Vs concentration of final dose, the calibration curves were created. As a result, the relevant regression equation has been calculated.

**Assay of RMD drug in pharmaceutical preparations**

A proposed method differs from all previous ways for estimating the researched RMD in pharmaceutical formulations in that it just needs to powder the precisely weighed IV injection dosage form in a porcelain mortar to reduce the size of the particle before FTIR measurement methods. Five repetition samples were used with the general suggested methods, as indicated in analytical procedure section. The amounts of the RMD drugs examined were estimated using the regression equation.

**3. Results**

Direct API solid-state analysis decreases the harmful effect on the environment and public health while also being better suitable for the analysis of pharmaceuticals with solubility issues. As a tool for quantitative evaluation the calibre of analytical techniques employed throughout the pharmaceutical production process, FTIR had widely utilised to detect and quantify API for a range of pharmaceuticals in recent years[13-18, 20-22]. The qualitative study for the analysed RMD medications has been conducted by evaluating the standard references of the researched pharmaceuticals to assure the lack of impurities, breakdown products, or interference from naturally occurring compounds. The quantitative study was done by measuring the absorbance of carbonyl peaks in the spectral region of 1695 to 1740 cm1 for the RMD medications that were tested (Figure 2). A chosen location for the unique carbonyl bands confirms that no additives from typical pharmaceutical excipients interfered with the measurement of the examined RMD medicines in commercially sold injections. Different concentration levels of the RMD medicines were used to create analytical FTIR spectra (Figure 3).

**Method validation**

Through ICH guidelines, the provided methods had wholly verified[19].

**Range and linearity**

The calibration curves had made by graphing the absorbance readings against their respective solutions at five different concentration levels. The correlation coefficient (r) of 0.9997 and the determination coefficient (rs) of 0.999 for RMD were achieved by aggregating three analytical calibration graphs of the drug. The statistical parameters for the mentioned drugs were calculated using the resulting linear regression analysis for the recommended approach, as Table 1 shows.

**Quantitation and of detection limits**

Using the formula LOQ = 10 S/b, where S is the mean of the standard deviation of the intercepts and b is the slope of the calibration graphs, the LOQ values for the medications under investigation were determined following ICH recommendations. LOD value was determined using the formula LOD = 3.3 S/b. The results showed that the LOQ and LOD were 4.42 mg/g and 1.97 mg/g, respectively.

**Accuracy**

Recovery experiments as a proposed ATR-FTIR approach had been carried out using RMD's regression equations, and each was examined at three distinct concentration levels (80, 100, and 120 percent). The acceptable accuracy of the recommended approach has been established, as shown in Table 2, by comparing the % recovery resulting values to the actual values.

**Precision**

Three concentration levels within the prescribed linear range of RMD genuine powders were evaluated for three days to determine inter-day precision (intermediate precision). Intra-day accuracy (repeatability) has been dedicated by measuring three concentration levels of RMD genuine powders within the prescribed linear range on the same day. Table 3 revealed that the recommended approach had good precision at the intermediate precision and repeatability precision stages, as the % RSD value for intra-day precision was 1.28, and the % RSD value for inter-day precision was 1.11 for RMD.

**Applications**

**Application to marketed injection**

Remdesivir in its pharmaceutical injectable form were analysed using the present analytical technique (DESREMTM 100 mg and COVIFORTM 100 mg injection). The proposed ATR FTIR method's label claim % (recovery ± SD) was 101 ± 1.2 for RMD, respectively. The Student's t-test and the variance ratio F-test has been utilized to evaluate the findings of the recommended and accessible spectroscopic methods [9,18]. As the calculated values seem to be lower than the corresponding values, illustrating the same precision and accuracy within the evaluation of RMD drug in its injection dosage through proposed technique, there has been no appreciable difference among the results obtained by calculation of the recommended

ATR-FTIR system and results acquired by the destructive spectroscopic methods (Table 4) [22-42].

## 4. Discussion

In order to make sure the RMD drugs under analysis were devoid of contaminants, degradation byproducts, or interference from natural substances, a qualitative study of the drugs entailed evaluating their standard references. The carbonyl peak absorbance for the evaluated RMD medicines was measured for the quantitative analysis, with measurements taken within the spectral region of 1695 to 1740 cm-1. We confirmed the absence of common pharmaceutical additive interference in the commercially available injections of the RMD drugs under investigation by carefully choosing particular positions for the unique carbonyl bands. The LOD was 1.97 mg/g, and the LOQ was 4.42 mg/g, according to the data. The percentage RSD values for intra-day precision and inter-day precision for RMD were 1.28 and 1.11, respectively, indicating the intermediate precision and repeatable precision phases. The label claim percentage (recovery ± SD) for RMD using the suggested ATR FTIR technique was 101 ± 1.2. The advantages of the proposed approach include the ability to directly use the researched API medication without requiring the preparation of a solid sample and the removal of organic chemical solvents from the analytical procedure.

## 5. Conclusion

This present study provides a fast and reliable ATR-FTIR technique for analysing remdesivir in both API material and pharmaceutical dose forms. The suggested method has the benefit of allowing for direct API drug of the investigated without the necessity for pretreatment of a sample in solid form, and also the elimination of organic chemical solvents from the analytical process. Furthermore, the proposed method may be beneficial for doing a quick green analysis of RMD studies at a pharmaceutical industrial level.

**Acknowledgement:**

We would like to express our gratitude to Mylan Pharma Pvt. Ltd. (Bangalore, India) for providing the pure drug sample (API). The Central Instrumental Lab. (ATR-FTIR

spectrometer), SKBCOP, Kamptee, facility utilized in this investigation was provided by Dr. Milind J. Umekar and Dr. Krishna R. Gupta.

**Declaration of competing interest:** Not Applicable

**Conflict of Interest:** Not Applicable

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**Ethical Approval:** Not Applicable

**Disclosure statement**

The authors do not have any conflict of interest

**Summary:**

Remdesivir is a broad-spectrum antiviral medication used to treat COVID-19. A green analytical chemistry technique was developed to measure the substance in both its prescription dose and pure form. For the non-destructive, sensitive, and accurate detection of remdesivir in pharmaceutical formulations, the technique used attenuated total reflection-Fourier transform infrared (ATR-FTIR) spectroscopy. The approach showed linearity across doses of 2.0–10.0 mg by detecting the stretching bands of the carbonyl group within a specified spectral range. Both method versions also showed strong correlation coefficients. For every approach, the limits of detection and quantification were established. The analytical approach that was developed generated findings that were in line with conventional, destructive approaches while also adhering to the principles of green chemistry. Remdesivir's quantitative pharmaceutical analysis now has a feasible choice thanks to this method, which is praised for its speed, accuracy, precision, cost-effectiveness, and environmental friendliness.

**Authors' contributions:**

All authors have read and approved the manuscript. SR contributed in preparation primary content. He performed extensive literature survey and compile the content. SR contributed in

preparation of figures and table. SB contributed in checking of manuscript and correction of grammatical mistake. SR contributed in preparation of figure. SB contributed in finalization of manuscript and in its correction. SB contributed in finalization of content, preparation of concrete manuscript and in schematic presentation of content.

## Abbreviations

| | |
|---|---|
| HCV | Hepatitis C virus |
| RMD | Remdesivir |
| DAA | Direct-acting anti-HCV |
| NS5B | Nucleotide analogue |
| GAC | Green analytical chemistry |
| FDA | Food and drug administration |
| API | Active pharmaceutical ingredients |
| HPLC | High-performance liquid-chromatography |
| HPTLC | High-performance thin-layer chromatography |
| LC-MS | Liquid-chromatography-mass spectroscopy |
| ATR | Attenuated total reflection |
| FTIR | Fourier transform infrared spectroscopy |
| LOD | Limit of detection |
| LOQ | Limit of quantification |
| RSD | Relative standard deviation |
| SD | Standard deviation |
| ICH | International council for harmonisation |
| IV | Intravenous |

## References

[1] Gower, E.; Estes, C.; Blach, S.; Razavi-Shearer, K.; Razavi, H.: Global epidemiology and genotype distribution of the hepatitis C virus infection. J. hepatology. (2014), 61(1), S45-57. **DOI:** 10.1016/j.jhep.2014.07.027.

[2] Aboras, S.; Abdine, H.; Ragab, M.; Korany, M.: A review on analytical strategies for the assessment of recently approved direct acting antiviral drugs. Critical Reviews in Analytical Chemistry, (2022), 52(8), 1878-1900. **DOI:**10.1080/10408347.2021.1923456.

[3] Bulduk, I.; Akbel, E.: A comparative study of HPLC and UV spectrophotometric methods for remdesivir quantification in pharmaceutical formulations. Journal of Taibah University for Science. (2021), 15(1), 507-13. **DOI:** 10.1080/16583655.2021.1991737.

[4] Hamdy, M.; Abdel Moneim M.; Kamal M.: Accelerated stability study of the ester prodrug remdesivir: Recently FDA- approved Covid- 19 antiviral using reversed- phase-HPLC with fluorimetric and diode array detection. Biomedical Chromatography. (2021), 35(12), e5212. **DOI:** 10.1002/bmc.5212.s.

[5] Nguyen, R.; Goodell, J.; Shankarappa, P.; Zimmerman, S.; Yin, T.; Peer, C.; et al.: Development and validation of a simple, selective, and sensitive LC-MS/MS assay for the quantification of remdesivir in human plasma. Journal of Chromatography B. (2021), 1171,122641, 01-07. **DOI:** 10.1016/j.jchromb.2021.122641.

[6] Acquavia, M.; Foti, L.; Pascale, R.; Nicolò, A.; Brancaleone, V.; Cataldi, T.; et al.: Detection and quantification of Covid-19 antiviral drugs in biological fluids and tissues. Talanta. (2021), 224, 121862, 1-27. **DOI;** 10.1016/j.talanta.2020.121862.

[7] Hu W, Chang L, Ke C, Xie Y, Shen J, Tan B, Liu J. Challenges and stepwise fit-forpurpose optimization for bioanalyses of remdesivir metabolites nucleotide monophosphate and triphosphate in mouse tissues using LC–MS/MS. Journal of Pharmaceutical and Biomedical Analysis. (2021), 194, 113806, 1-10. **DOI:** 10.1016/j.jpba.2020.113806.

[8] Yuksel, N.; Kose, A.; Fellah, M.: The supramolecularly complexes of calix [4] arene derivatives toward favipiravir antiviral drug (used to treatment of COVID-19): a DFT study on the geometry optimization, electronic structure and infrared spectroscopy of adsorption and sensing. Journal of Inclusion Phenomena and Macrocyclic Chemistry. (2021), 101(1), 77-89. **DOI;** 10.1007/s10847-021-01087-1.

[9] Du, P.; Wang, G.; Yang, S.; Li, P.; Liu, L.: Quantitative HPLC-MS/MS determination of Nuc, the active metabolite of remdesivir, and its pharmacokinetics in rat. Analytical and Bioanalytical Chemistry. (2021), 413(23), 5811-20. **DOI:** 10.1007/s00216-021- 03561-8.

[10] Xiao, D.; Ling, K.; Tarnowski, T.; Humeniuk, R.; German, P.; Mathias, A.; et al.: Validation of LC-MS/MS methods for determination of remdesivir and its metabolites GS-441524 and GS-704277 in acidified human plasma and their application in COVID19 related clinical studies. Analytical Biochemistry. (2021), 617, 114118. **DOI:** 10.1016/j.ab.2021.114118.

[11] Armenta, S.; Garrigues, S.; de la Guardia, M.: Green analytical chemistry. TrAC Trends in Analytical Chemistry. (2008), 27(6), 497-511. **DOI:** 10.1016/j.trac.2008.05.003.

[12] Curyło, J.; Wardencki, W.; Namieśnik, J.: Green Aspects of Sample Preparation-a Need for Solvent Reduction. Polish Journal of Environmental Studies.16(1), (2007).

[13] Bunaciu, A.; Aboul-Enein H.; Fleschin S.: Application of Fourier transform infrared spectrophotometry in pharmaceutical drugs analysis. Applied Spectroscopy Reviews. (2010), 45(3), 206-19. **DOI:** 10.1080/00387011003601044.

[14] Tótoli, E.; Salgado, H.: Development and validation of the quantitative analysis of ampicillin sodium in powder for injection by Fourier-transform infrared spectroscopy (FT-IR). Physical Chemistry. (2012), 2(6),103-8. **DOI:** 10.5923/j.pc.20120206.04.

[15] de Haro Moreno, A.; Salgado. H.: Development and validation of the quantitative analysis of ceftazidime in powder for injection by infrared spectroscopy. Phys. Chem.. (2012), 2, 6-11. **DOI:** 10.5923/j.pc.20120201.02.

[16] Kogawa, A.; Salgado, H.: Development and validation of infrared spectroscopy method for the determination of darunavir in tablets. Physical Chemistry. (2013), 3(1), 1-6. **DOI:**10.5923/j.pc.20130301.01.

[17] Ferreira, M.; Braga, J.; Sena, M.: Development and validation of a chemometric method for direct determination of hydrochlorothiazide in pharmaceutical samples by diffuse reflectance near infrared spectroscopy. Microchemical Journal. (2013), 109, 158-64. **DOI:** 10.1016/j.microc.2012.03.008.

[18] De Bleye, C.; Chavez, P.; Mantanus, J.; Marini, R.; Hubert, P.; Rozet, E.; et al.: Critical review of near-infrared spectroscopic methods validations in pharmaceutical applications. Journal of pharmaceutical and biomedical analysis. (2012), 69, 125-32. **DOI:** 10.1016/j.microc.2012.03.008.

[19] Guideline IC. Q2 (R1): validation of analytical procedure: text and methodology. ICH, London. 2005 Nov. **DOI:** 10.1016/j.jpba.2012.02.003.

[20] Hamed, R.; Mohamed, E.; Sediri, K.; Khan, M.; Rahman, Z.: Development of stable amorphous solid dispersion and quantification of crystalline fraction of lopinavir by spectroscopic-chemometric methods. International Journal of Pharmaceutics. (2021), 602, 120657. **DOI:** 10.1016/j.ijpharm.2021.120657.

[21] Noureldeen, D.; Boushra, J.; Lashien, A.; Hakiem, A.; Attia, T.: Novel environment friendly TLC-densitometric method for the determination of anti-coronavirus drugs "Remdesivir and Favipiravir": Green assessment with application to pharmaceutical

formulations and human plasma. Microchemical Journal. (2022), 174, 107101. **DOI:** 10.1016/j.microc.2021.107101.

[22] Reddy, H.; Pratap, S.: Chandrasekhar, N.; Shamshuddin, S.: A Novel Liquid Chromatographic Method for the Quantitative Determination of Degradation Products in Remdesivir Injectable Drug product. Journal of Chromatographic Science. (2022), 60(2), 194- 200. **DOI:** 10.1093/chromsci/bmab042.

[23] Patil, D.; Rangari, S.; Chaudhari, S.; Bhurat, M.: Analytical Method Development for the Determination and Quantification of Ramipril in Pharmaceutical Formulation by HPLC. International Journal for Research Trends and Innovation (IJRTI). (2022), 7(9), 910 -915. **DOI**:10.2209124.

[24] Masne, T.; Rangari, S.; Gupta, K.; Umekar, M.: Method Development and Validation of UV-Spectrophotometric Estimation of Hydroxychloroquine Sulphate in Bulk and Pharmaceutical Dosage Form. Asian Journal of Chemical Sciences (AJCS). (2023) 13(4), 39-52. **DOI**:10.9734/AJOCS/2023/v13i4248.

[25] Rangari, S.; Rane, B.; Baviskar S.; et al.: Thin layer Chromatography of Ibogaine from plant extract of Tabernanthe Iboga. Journal of Current Pharma Research (JCPR). (2015), 5 (3), 1565-1568. **DOI**:10.25166.

[26] Rangari, S.; Bari, S.: Analytical Profiling of Sofosbuvir as NS5B Protein Inhibitor for Oral Drug Delivery: Method development and Validation. Bulletin of Faculty of Pharmacy Cairo University (BFPCU), (2022), 60(2), 33-51. **DOI:** 10.54634/2090-9101.1036.

[26] Rangari, S.; Bari, S.; Gupta, K.; Umekar M.: Particle Technology: A Great Role in Method Development in High Performance Liquid Chromatography. Journal of Electronics Information Technology Science and Management (JEITSM), (2023), 13(1), 6-37. **DOI:**10.37896/JEISMV13.1/232**.**

[27] Patil, P.; Rangari, S.: Research on analytical methods of analysis of Ranolazine: A Review. Himalayan Journal of Health Sciences (HJHS). (2020), 30-40. **DOI:** 10.22270/hjhs.v5i4.79

[28] Patil, P.; Rangari, S.; Patil, P.: Recent Research on Analytical Methods of Analysis of Artemether and Lumefantrine: a Review. Himalayan Journal of Health Sciences (HJHS). (2020), 16-29. **DOI:** 10.22270/hjhs.v5i4.71

[29] Mantanus, J., Ziemons, E., Lebrun, P., Rozet, E., Klinkenberg, R., Streel, B., Hubert, P. Moisture content determination of pharmaceutical pellets by near infrared spectroscopy: method development and validation. Analytica chimica acta, (2009), *642*(1-2), 186-192. **DOI:** 10.1002/dta.47.

[30] Singh, P.; Jangir, D.; Mehrotra, R.; Bakhshi, A.: Development and validation of an infrared spectroscopy- based method for the analysis of moisture content in 5- fluorouracil. Drug Testing and Analysis, (2009), *1*(6), 275-278. **DOI:** 10.1016/j.aca.2008.12.031.

[31] Biagi, D.; Nencioni, P.; Valleri, M.; Calamassi, N.; Mura, P.: Development of a Near Infrared Spectroscopy method for the in-line quantitative bilastine drug determination during pharmaceutical powders blending. Journal of Pharmaceutical and Biomedical Analysis, (2021), *204*, 114277. **DOI:** 10.1016/j.jpba.2021.114277.

[32] Li, Y.; Igne, B.; Drennen J.; Anderson, C.: Method development and validation for pharmaceutical tablets analysis using transmission Raman spectroscopy. International journal of pharmaceutics, (2016), *498*(1-2), 318-325. **DOI:** 10.1016/j.ijpharm.2015.11.049

[33] Bansal, R.; Guleria, A.; Acharya, P.: FT-IR method development and validation for quantitative estimation of zidovudine in bulk and tablet dosage form. Drug research, (2013), 165-170,. **DOI:** 10.1055/s-0032-1333297.

[33] Rangari, S.; Patil, M.: RP- HPLC Method Development for Simultaneous Estimation of Sitagliptin Phosphate and Metformin Hydrochloride in Pharmaceutical Dosage Form. International Journal of Research in Pharmacy and Chemistry (IJRPC), (2021), 11(3), 64-70. **DOI:**10.33289/IJRPC.09.7.2021.11(28).

[34] Rangari, S.; Jamullamudi, R.; Chouhan, M.; Ranjan, R.; Dandapat, C.; Maity, A.; Bhattacharya, S.; Ambasana P.: Synthesis of Novel Pyridine-Schiff Base Derivatives for Potential Treatment of Tuberculosis. Eur. Chem., 12 Bull. (2023), (s3), 7646 – 7654. **DOI:** 10.31838/ecb/2023.12.s3.845.

[35] Kashid, V.; Rangari, S.; Afzal, S.; Ganguly, P.; Singh, A.; Patel, A.; Ranjan, R.; Baviskar. M.: Novel Herbal Formulations for The Prevention and Management of Diabetes and Cardiovascular Disorder. Eur. Chem., 12 Bull. (2023), (s3), 7558 – 7565. **DOI:** 10.31838/ecb/2023.12.s3.835.

[36] Rangari S.; Bari S.: Quantitative Determination of Sofosbuvir In Pure And Pharmaceutical Dosages Form By ATR-FTIR Spectroscopic As A Green Method. Int. J. of Pharm. Sci., (2024), 2(2), 570-583. **DOI:** 10.5281/zenodo.10688689.

[37] Nithila, P.; Raghavendrababu, N.; Padmavathi, Y.; Neena, G.; Sushma, K.; Poojitha, A.: New FTIR Method Development and Validation for Quantitative Analysis of Favipiravir in Bulk and Pharmaceutical Dosage Forms. Int J Curr Pharm Res, (2022), *14*(5), 25-29. **DOI:**10.22159/ijcpr.2022v14i5.2022.

[38] Raasi, K.: Analytical method development and validation of Remdesivir in bulk and pharmaceutical dosage forms using reverse-phase-high performance liquid chromatography. International Journal of Phramaceutical Sciences & Clinical Research, (2021), *1*(2). **DOI:** 10.22377/ijpscr.v1i2.35.

[39] Tiris, G.; Gazioglu, I.; Furton, K.; Kabir, A.; Locatelli, M.: Fabric phase sorptive extraction combined with high performance liquid chromatography for the determination of favipiravir in human plasma and breast milk. Journal of Pharmaceutical and Biomedical Analysis, (2023), *223*, 115131. **DOI:** 10.1016/j.jpba.2022.115131.

[40] Rad, A.; Ardjmand, M.; Esfahani, M.; Khodashenas, B.: DFT calculations towards the geometry optimization, electronic structure, infrared spectroscopy and UV–vis analyses of Favipiravir adsorption on the first-row transition metals doped fullerenes; a new strategy for COVID-19 therapy. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, (2021), *247*, 119082. **DOI:** 10.1016/j.saa.2020.119082.

[41] Hatipoglu, M.; Zaker, Y.; Willett, D.; Gupta, N.; Rodriguez, J.; Patankar, S.; Yilmaz, H.: Old Polymorph, New Technique: Assessing Ritonavir Crystallinity Using Low-Frequency Raman Spectroscopy. Analytical Chemistry, (2023) *95*(41), 15325-15332. **DOI:** 10.1021/acs.analchem.3c02781.

[42] Darwish, A.; Khalil, Y.; Darwish, W.; Alzoman, Z.; & Al-Hossaini, M.: Synthesis, spectroscopic and computational characterization of charge transfer complex of remdesivir with chloranilic acid: Application to development of novel 96-microwell spectrophotometric assay. *Journal of Molecular Structure*, (2022), *1263*, 133104. **DOI:** 10.1016/j.molstruc.2022.133104.

**Original Article**

# Quantitative Determination of Remdesivir in Pure and Pharmaceutical Dosages form by ATR-FTIR Spectroscopic as a Green Method.

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## DECLARATIONS

### Ethics approval and consent to participate

♣ No animal or human was used during this experimental study

### Consent for publication

♣ The research work embodied in this article is the original research work of me and my team. It is neither published nor being considered for publication elsewhere. On behalf of all the authors, I will act as guarantor and will correspond with the journal from this point onward.

### Competing interests

♣ The author declares that they have no competing interests.

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♣ Not Applicable

**Ethical Approval:** Not Applicable

**Author's contribution**

♣ All authors have read and approved the manuscript. SR contributed in preparation primary content. He performed extensive literature survey and compile the content. SR contributed in preparation of figures and table. SB contributed in checking of manuscript and correction of grammatical mistake. SR contributed in preparation of figure. SB contributed in finalization of manuscript and in its correction. SB contributed in finalization of content, preparation of concrete manuscript and in schematic presentation of content.

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♣ We would like to express our gratitude to Mylan Pharma Pvt. Ltd. (Bangalore, India) for providing the pure drug sample (API). The Central Instrumental Lab. (ATR-FTIR spectrometer), SKBCOP, Kamptee, facility utilized in this investigation was provided by Dr. Milind J. Umekar and Dr. Krishna R. Gupta.

**Figure captions**

Figure 1: Chemical structures of remdesivir.

Figure 2: FTIR spectra of standards remdesivir (API) (a), marketed samples DESREMTM (b) and COVIFORTM (c) (2.0 mg/g).

Figure 3: FTIR spectra of different concentrations of standard RMD.

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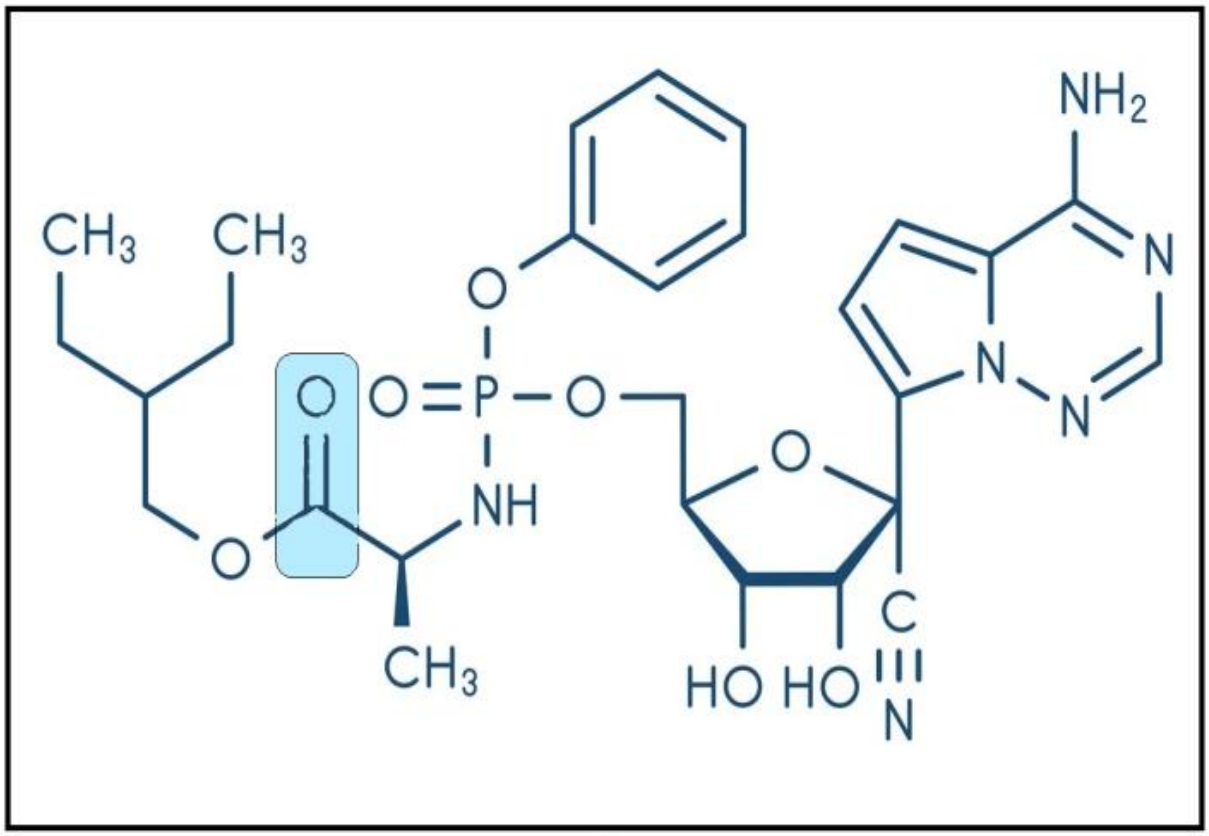


**Figure 1: Chemical structures of remdesivir.**

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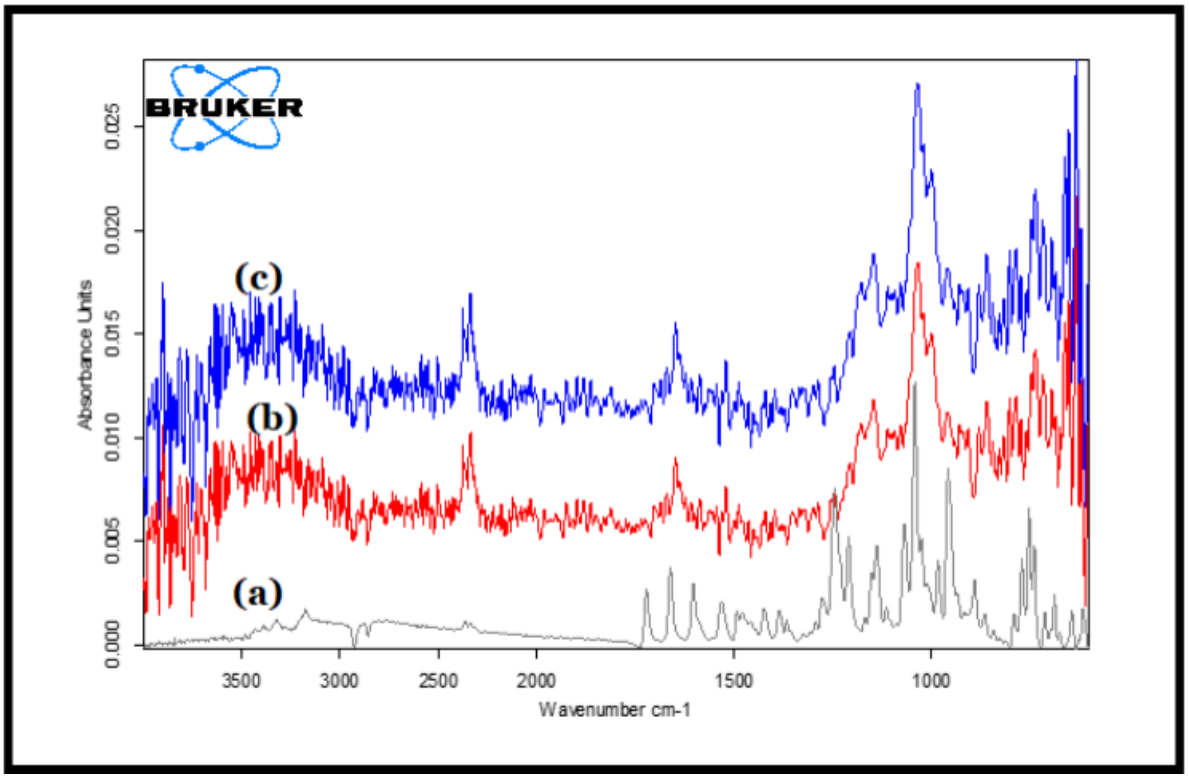


**Figure 2: FTIR spectra of standards remdesivir (API) (a), marketed samples DESREMTM (b) and COVIFORTM (c) (2.0 mg/g).**

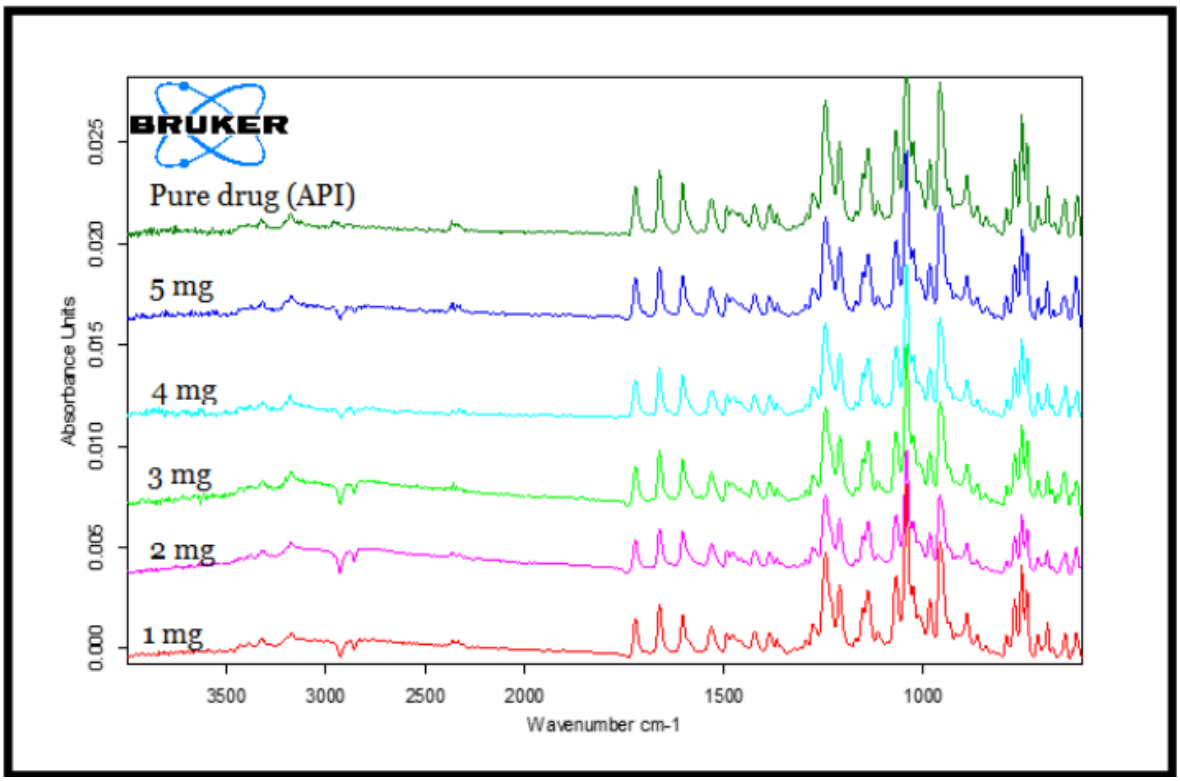


**Figure 3: FTIR spectra of different concentrations of standard RMD.**

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**Table captions**

Table 1: Validation parameters and regression equation for the proposed FTIR method.

Table 2: Evaluation of accuracy for the analysis of RMD by the proposed FTIR method.

Table 3: Precision data for the analysis of RMD by the proposed FTIR method.

Table 4: Analysis of remdesivir in their pharmaceutical preparations.

**Table 1: Validation parameters and regression equation for the proposed FTIR method.**

| Sr. No. | Parameter | Results (mean ± SD) |
|---|---|---|
| 1 | Linear range (mg/g) | 1.0 – 5.0 |
| 2 | Slope | 1.42 × 10−2 |
| 3 | SD of slope (Sb) | 1.9 × 10−4 |
| 4 | Intercept | 5.5 × 10−2 |
| 5 | SD of intercept (Sa) | 2.1 × 10−3 |
| 6 | Correlation coefficient (r) | 0.9997 |
| 7 | Determination coefficient ($r^2$) | 0.9999 |
| 8 | Number of determinations | 5 |
| 9 | Limit of quantitation (mg/g) | 4.42 ±0.02 |
| 10 | Limit of detection (mg/g) | 1.97 ±0.09 |

*Values are presented as the mean ± SD (n = 3).

**Table 2: Evaluation of accuracy for the analysis of RMD by the proposed FTIR method.**

| Marketed formulation | Drug Taken (mg/g) | Added concentration (%) | ∗Recovered amount (%) (mean ± SD) | % RSD |
|---|---|---|---|---|
| DESREM™ 100mg | 5 | 80 | 100.63 ± 0.22 | 0.22 |
| | 5 | 100 | 98.83 ± 0.31 | 0.31 |
| | 5 | 120 | 100.37 ± 0.19 | 0.17 |
| COVIFOR™ 100mg | 5 | 80 | 99.51 ± 0.29 | 0.28 |
| | 5 | 100 | 101.17 ± 0.17 | 0.18 |
| | 5 | 120 | 100.58 ± 0.26 | 0.26 |

∗Values presented as mean value of three determination (n = 3).

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**Table 3: Precision data for the analysis of RMD by the proposed FTIR method.**

| Sr. No. | Interday precision (intermediate precision) | | | Intraday precision (repeatability precision) | | |
|---|---|---|---|---|---|---|
| | **Conc. Level (mg/g)** | **∗Average peak area (mean ± SD)** | **% RSD** | **Conc. Level (mg/g)** | **∗Average peak area (mean ± SD)** | **% RSD** |
| **1** | 5 | 225.51 ± 0.98 | 1.84 | 5 | 224.56 ± 0.85 | 1.77 |
| **2** | 10 | 484.54 ± 0.76 | 0.49 | 10 | 483.82 ± 0.45 | 0.55 |
| **3** | 15 | 902.16 ± 1.21 | 1.00 | 15 | 901.13 ± 1.32 | 1.52 |
| | Mean % RSD | | 1.11 | Mean % RSD | | 1.28 |

∗Values presented as mean value of three determination (n = 3).

**Table 4: Analysis of remdesivir in their pharmaceutical preparations.**

| Marketed Formulation (Injection) | % Recovery of Proposed method (mean ± SD) | t-value | F-value |
|---|---|---|---|
| DESREM$^{TM}$ 100 mg | 99.46 ± 1.72 | 1.485 | 3.568 |
| COVIFOR$^{TM}$ 100 mg | 99.69 ± 1.83 | 1.489 | 3.567 |

* Values are presented as the mean ± SD (n = 5)

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## Graphical Abstract: