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# Development and Validation of UPLC-MS / MS Method for Obtaining Favipiravir Tablet Dosage form and Evaluation of its Behavior Under forced Conditions

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author SG designed the study, managed the literature searches and wrote the first draft of the manuscript. AH and IB managed the analyses of the study, and performed the statistical analysis. All authors read and approved the final manuscript.*

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## ABSTRACT

**Aims:** Favipiravir (FVP) is a drug developed against RNA viruses. It is a drug that is used actively in the treatment of coronavirus. In vitro and in vivo investigations have shown that it inhibits the virus. In this study, a recovery study of tablet formulations was carried out by developing a UPLC-MS/MS method, which is used extensively in pandemic conditions. In addition, stability studies of favipiravir agent under forced conditions were conducted. The validated method is selective, robust, simple and applicable for tablet analysis. C18 (4.6 mm × 50 mm, 2.7 μm) column was used as the stationary phase and water-methanol (80-20 v/v) containing 0.1% formic acid was used as the mobile phase. UPLC optimization; It was conducted at a wavelength of 222 nm and a flow rate of 0.8 mL/min at 40 °C, retention time was 1.155 min. The electrospray jet stream ionization source was analyzed using mass spectrometry in negative ion mode. The molecular peak for Favipiravir was [M-1] 155.9, and the daughter ion determined 112.6. The stability test method was carried out in accordance with the ICH procedure. Reaction and degradation rates of the active substance

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under various forced conditions (acidic, basic, oxidative, UV light and thermal conditions) were investigated. The products formed by the decomposition of the active substance under stress conditions were determined by mass spectroscopy.

*Keywords: Drug analysis; degradation products; ICH; stability-indicating.*

## 1. INTRODUCTION

Favipiravir is an antiviral drug with molecular formula $C_5H_4FN_3O_2$ (6-fluoro-3-hydroxypyrazıne-2-carboxamide) with molecular mass 157.1 and molecular shape shown in Fig. 1. [1]. Despite the fact that Favipiravir was licensed for use as a novel flu treatment in China on February 15-2020, clinical trials for COVID-19 treatment are still underway. Favipiravir is an RNA-dependent RNA polymerase (RdRp) inhibitor of a new kind. [2]. Favipiravir can inhibit the replication of flavi-, alpha-, filo-, bunya-, arena-, neuro-, and other RNA viruses in addition to its anti-influenza virus activities. [3]. There are LC-MS/MS studies in the literature on the determination of favipiravir from a pharmaceutical dosage form. Studies with HPLC method and [4] continue in the literature and there is a UPLC-MS/MS study [5] on detection from human plasma. In an additional study, the degradation kinetics of favipiravir was studied by LC-MS method under different forced conditions. The active ingredient was validated and the LOD-LOQ was reported to be higher than our study [6]. In another study, a new LC-MS method was developed for the determination of favipiravir. With the developed method, two different drugs containing favipiravir were determined from adult patients [7]. In other studies, the determination of favipiravir from rat plasma by HPLC was studied pharmacologically [8]. In a different study, the HPLC method was developed for the simultaneous determination of favipiravir and peramivir and the determination of their degradation products. [9] Advanced methods are needed to monitor purity and related spoilage products during the preparation of pharmaceutical forms [10]. The impurity profile and stability of a drug substance are crucial in the safety assessment and manufacturing process.[11]. Stress tests are conducted to obtain information about the degradation products and degradation mechanisms of active substances under forced conditions. In line with “Good Manufacturing Practices” on the production and consumption of favipiravir, various updates are published by the "European Medicine Agency" publications, "ICH" guidelines, "WHO", "European pharmacopoeia" during the pandemic.

The stability of the active ingredient in the formulation under storage conditions is very important for the use of medicinal drugs. As a result, the active ingredient's degradation behavior is critical in determining the shelf life of a pharmaceutical product. Knowing the active ingredient's breakdown products can aid in preventing the creation of unwanted by-products that arise during storage. The impurity profile and stability of a drug substance are also important in the safety assessment and production process. Stress tests are performed to obtain information about the degradation products and degradation mechanisms of drug agents under forced conditions [12-14].

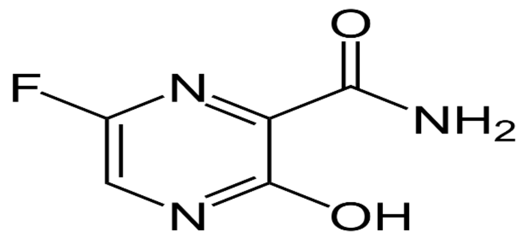


**Fig. 1. Favipiravir molecule**

## 2. MATERİALS AND METHODS

### 2.1 Materials

Chromatographic analyzes were performed on Agilent 1200 infinity UPLC device with DAD detector, and mass spectroscopy analyzes were performed on Agilent 6460 triple quadrapole ms/ms device. Perkin Elmer Lambda-35 device was used as UV spectroscopy. Memmert brand oven and Bandelin brand ultrasonic bath were used in the analysis. In this work, analytical grade compounds were employed without further purification. Hydrochloric acid (37%, Sigma-Aldrich), sodium hydroxide (Sigma-Aldrich), hydrogene peroxide (30%, Sigma-Aldrich), formic acid (99%, Sigma-Aldrich) and HPLC-grade methanol (≥99.9%, Sigma-Aldrich) were used. Tobio Novelfarma provided the FVP active ingredient and tablets (favira, 200 mg) which were obtained using a Milli-Q system (Millipore) with conductivity less than 18.2 S $cm^{-1}$. (Istanbul, Turkey).

### 2.2 Preparation of Standard Solutions

100 mg of active ingredient was carefully weighed and dissolved in roughly 20 mL of ultrapure water before being transferred to a 100 mL measuring flask. The volume of the stock solution was increased to 100 mL using ultrapure water to obtain 1 mg $mL^{-1}$. The resulting stock solution was filtered through a 0.45 µm filter and sonicated. The stock solution was further diluted with deionized water before being fed into the system for analysis to obtain the needed standard solution concentration. (1-10 µg $mL^{-1}$).

### 2.3 Preparation of Sample Solution

Five FVP tablets were sensitively weighed before being transferred to a dry, clean mixture and pounded into a fine dust. The average weight of five tablets was 0.280 grams. Following that, 200 mg faripiravir tablet powder was placed to a 100 mL volumetric flask. 100 mL deionized water was added to the flask, which was then shaken for 10 minutes to completely disperse the components. After 30 minutes of sonication, the mixture was diluted to volume with ultrapure water to obtain a 500 µg $mL^{-1}$ solution, which was then filtered through a 0.45 µm filter.

### 2.4 Determination of $\lambda_{max}$

A UV spectrophotometer was used to scan a standard solution (10 g $mL^{-1}$) between 200 and 800 nm. (Perkin Elmer Lambda-35 UV-VIS spectrophotometer). The UV spectra of standard solution was used to calculate $\lambda$ max.

### 2.5 Chromatographic Conditions

On a Poroshell column, chromatographic analysis was done. 120 EC-C18 (4.6 mm × 50 mm, 2.7 µm). The mobile phase contained of methanol and $H_2O$ with formic acid % 0.1 (20:80, v/v). Before analysis, a 0.45 µm membrane filter was used to filter and degas the mobile phase, which was then pumped at 0.8 mL $min^{-1}$. The column's temperature has been set to 40 °C. The run time was 2 minutes under these conditions.

### 2.6 Mass Spectroscopy Conditions

The MS analysis was performed on UPLC-MS/MS instrument (Agilent 6460, USA) equipped with electrospray jet stream ionization source (AJS ESI). The data acquisition was under the control of Masshunter (Agilent, USA). First, the mass spectrometer was optimized for FVR and the daughter ion, fragmentor voltage and collusion energy were determined. Analyses were performed in positive and negative ion modes. But ionization was good in negative ion mode. Multiple reaction monitoring mode (MRM) was used to operate the MS/MS system. The typical MS parameters in negative ion mode were fragmentor voltage which was set at 80 V; cone gas flow 12 L/h; collusion energy 20 eV; capillary voltage at 3.5 kv; source temperature at 400 °C; desolvation gas flow at 11 L/min; and desolvation temperature at 300 °C. As a result of mass spectrometry analysis, favipiravir molecular mass peak was found to be M-1] 155.9 and main degradation product was 112.9.

### 2.7 Method Validation

Analytical validation of the method was performed according to the ICH procedure. Q2 (R1) criteria [11,12]. System applicability, linearity, the limit of detection (LOD), the limit of quantification (LOQ), accuracy, specificity, precision, and robustness were among the validation parameters.

### 2.8 System Suitability

The system appropriateness parameters (RSD% for retention time, RSD% for peak area, tailing factor and plate that is theoretical) were investigated after five replicate injections of standard solution (10 µg $mL^{-1}$) into the UPLC-MS/MS system.

### 2.9 Linearity

Six standard solutions in the concentration range of 1-10 µg $mL^{-1}$ were used to prepare the standard calibration. Each standard solution was analysed three times for two minutes in optimum chromatographic conditions. To test the linearity of the method, regression analysis was performed based on the peak area versus the concentration data.

### 2.10 Precision

To prove the precision of the method, intraday analyzes and interday analysis on five different days were performed. Studies on the interday and on intraday were completed with five injections at three different concentrations, 1, 4, and 10 µg $mL^{-1}$.

### 2.11 Accuracy

In order to prove the accuracy of the method, a recovery study was carried out using the standard addition method. Favipiravir recovery study was carried out by adding 80%, 100%, 120% of the amount found in the pure drug in three different concentrations to the samples.

### 2.12 Specificity

Specificity is that the method shows an analytical response in the presence of the sample. To prove the specificity of the method, mobile phase solution, drug solution and standard solution chromatograms were compared with each other. It was observed that the analyte peak was not observed in the empty mobile phase solution, and the chromatograms of the drug solution and standard reference substance were compatible with each other.

### 2.13 LOD and LOQ

These values were calculated using the standard deviation (s) and regression line slope (m), as shown in the equations below.

LOD = 3.3 * s/m

LOQ = 10 * s/m

### 2.14 Robustness

The robustness of analytical method was assessed by examining the effect of small but deliberate changes in method parameters on the analysis results. To test the robustness of the chromatographic method, the same sample was analyzed under different conditions such as changes in the mobile phase flow rate (±0.1 ml $min^{-1}$), methanol ratio in the mobile phase (±1%), and column temperatures (±2 °C), and the effect on the system suitability parameters has been observed.

### 2.15 Analysis of Marketed Formulations

Sample solution was prepared at a concentration of 10 µg $mL^{-1}$ and filtered using a 0.45 µm membrane filter. Then it was injected into the UPLC system.

### 2.16 Solution Stability

The stability of the solutions was tested during the day. The peak area and retention time of the sample and reference solutions were measured every 8 hours within 24 hours. All solutions were kept at room temperature (25 °C) and stored in the dark.

## 3. RESULTS AND DISCUSSION

### 3.1 Determination of λmax

The spectrophotometer had to be calibrated to zero first. Scanning in the range of 200 to 800 nm was used to determine the maximum absorption wavelength of favipiravir solution (10 µg $mL^{-1}$). Using the UV spectrum of the standard solution, the wavelength at which favipiravir exhibited the maximum absorbance was discovered to be 222 nm Fig. 2.

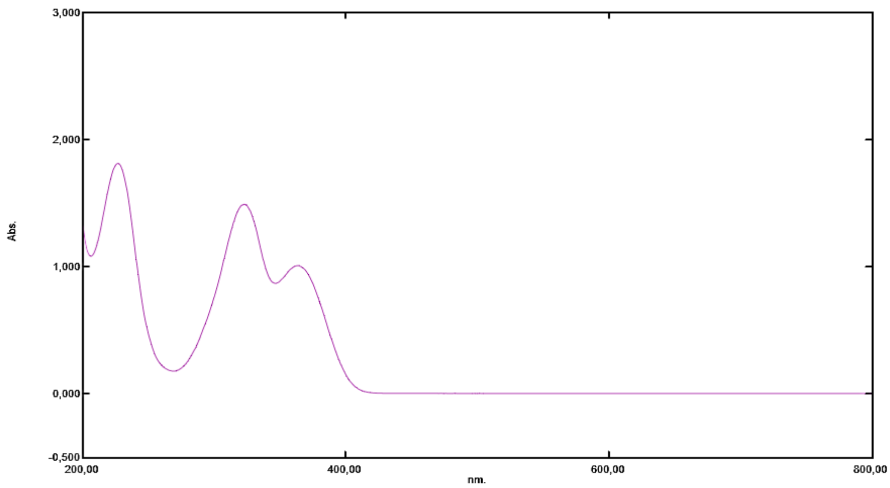


**Fig. 2. UV spectrum (Standard solution, 10 µg $mL^{-1}$)**

### 3.2 Method Validation

Within the scope of the chromatographic method development studies for the quantification of favipiravir, several preliminary studies have been carried out to optimize the conditions. At the beginning of the study, only ultra-pure water was tested without using organic modifiers, long analysis times were obtained. Different acetonitrile solution ratios were investigated to obtain optimal conditions. To obtain a good shape and symmetry of the favipiravir peak, ultrapure water containing 0.1% formic acid and methanol (80/20, v/v) were used as the mobile phase. Finally, this mobile phase provides more powerful theoretical plates (>7.000) and a peak queuing factor (<1.0). In addition to the analysis was carried out at 40 °C, which offers many advantages such as good chromatographic peak shape, increased column efficiency and low column pressure.

### 3.3 Linearity

It was made by diluting FVP, with ultrapure water to obtain calibration points in the 1-10 µg $mL^{-1}$ concentration range. Each prepared standard solution was injected three times under the specified chromatographic conditions. Linear regression analysis was used to test the linearity of the method in the UPLC-MS system in the concentration range of 1-10 µg $mL^{-1}$. Fig. 4 shows the calibration curve based on the concentration of the standards versus the peak area. The least squares approach was used to obtain the correlation coefficient, intersection, and slope of the regression. The relationship between the mean peak area, Y(n=3), and the concentration, X, was linear, as described by the equation Y = a + bX. As indicated in Table 1, the slope, intercept, and correlation coefficient (r) were 19.825, -7957, and 0.9999, respectively. Overlay chromatogram of FVP standard solutions (1, 2, 4, 6, 8, 10 µg $mL^{-1}$) was demonstrated in Fig. 3. Mass specturum was showed in Fig. 5.

### 3.4 Specificity

The method's specificity was determined by comparing the chromatograms produced for FVP standard, tablet, and blank solutions. The analysis of the chromatograms is shown in Fig. 6, 7 and 8 indicates that peaks because of excipients do not occur in pharmaceutical formulations.

**Table 1. Statistical data (Calibration curve, FVP)**

| Parameter | Value |
|---|---|
| Linearity range (µg $mL^{-1}$) | 1 - 10 |
| Slope | 19.825 |
| SD of Slope | 0.35 |
| Intercept | -7957 |
| SD of Intercept | 1662,99 |
| Correlation coefficient | 0.9999 |
| LOD/ LOQ (µg $mL^{-1}$) | 0.30/0.80 |

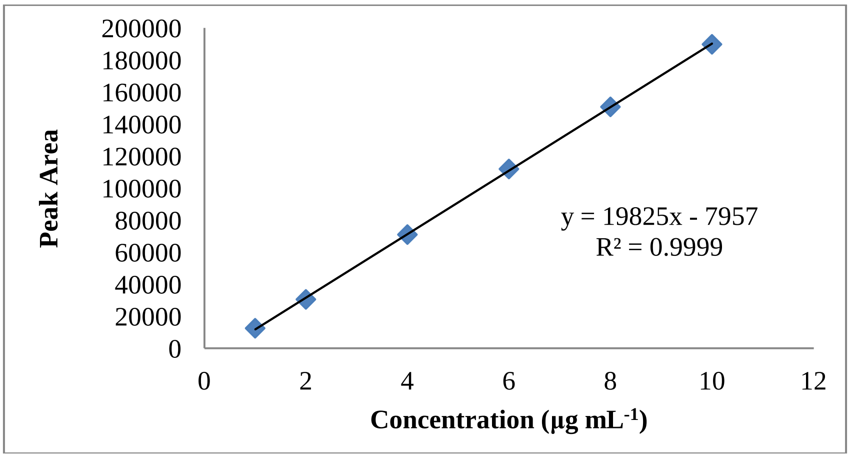


**Fig. 3. Calibration curve UPLC-MS/MS system**

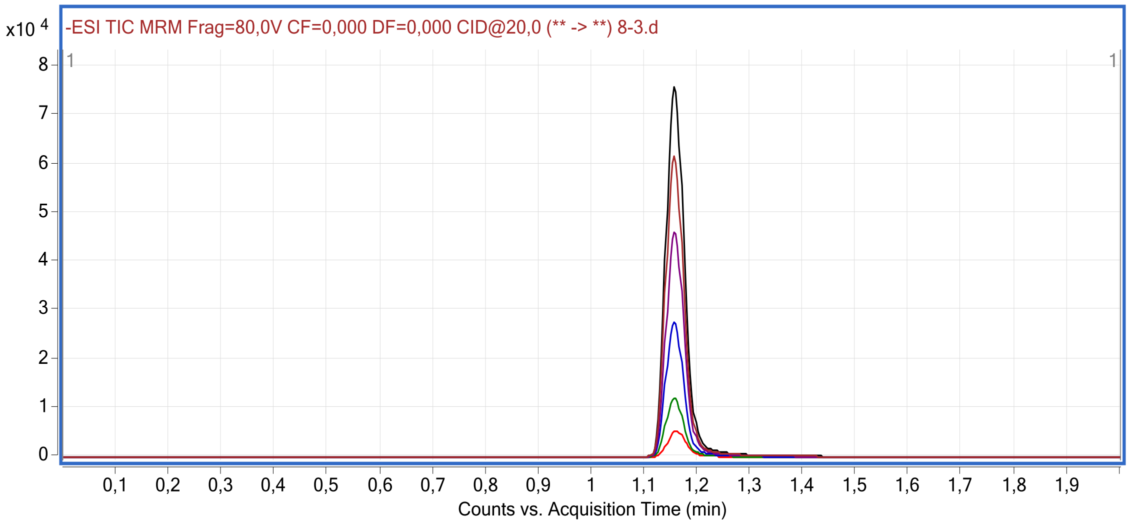


**Fig. 4. Overlay chromatogram (Standard solutions, 1, 2, 4, 6, 8, 10 µg mL$^{-1}$)**

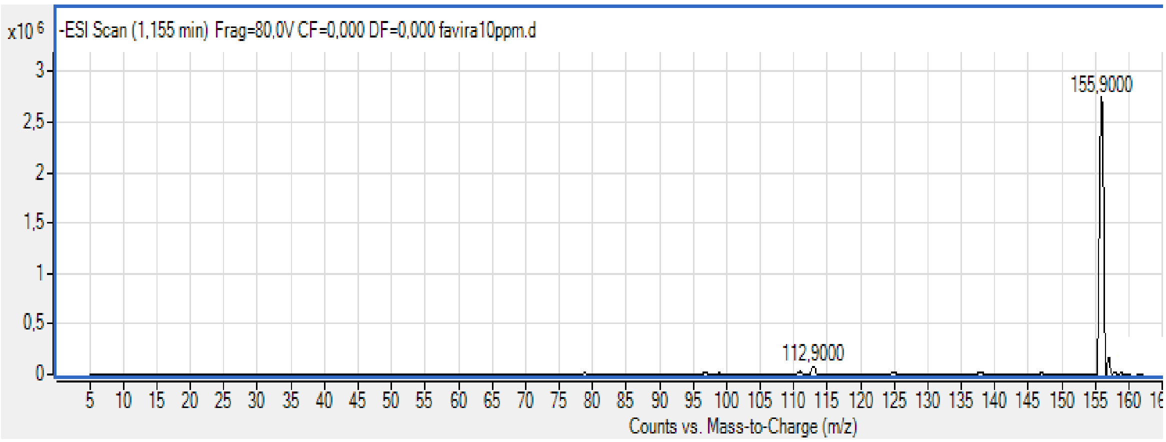


**Fig. 5. Mass spectrum FVR. Molecular peak 155.9 and daughter ion 122.9**

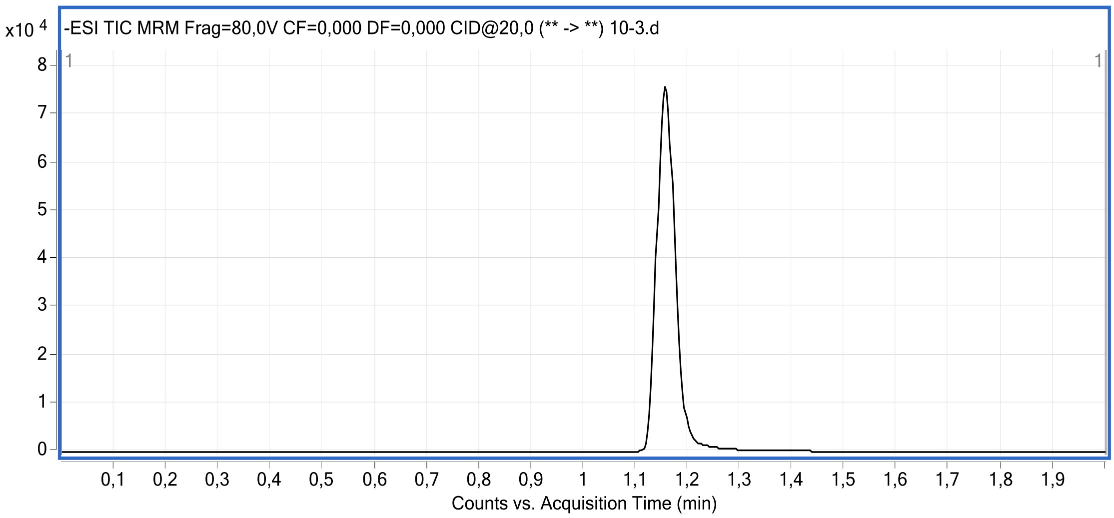


**Fig. 6. Chromatogram (Standard solution, 10 µg mL$^{-1}$)**

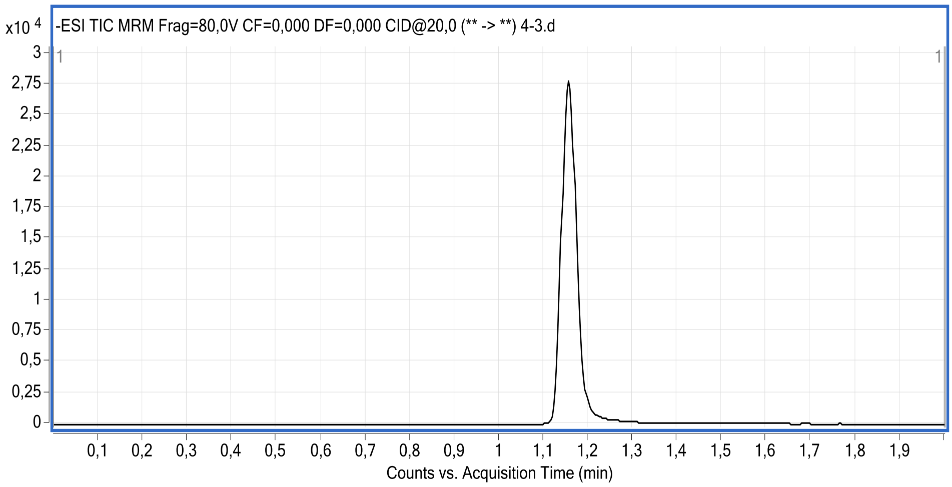


**Fig. 7. Chromatogram (Sample solution, 4 µg mL$^{-1}$)**

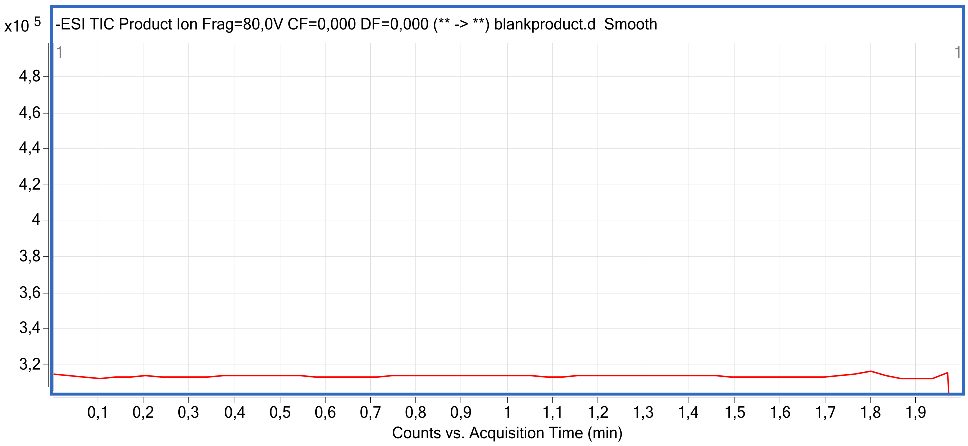


**Fig. 8. Chromatogram (Blank solution)**

### 3.5 Precision

The sensitivity of the method was tested by injecting doses of 1, 4, and 10 µg mL-1 five times on the same and different days, with the findings shown in Table 2. RSD values for retention time and peak area at all concentrations studied. were less than 0.54% and 2.0%, respectively. In these conditions, the precision of the analysis method was found to be suitable for the intended analysis.

**Table 2. Precision data**

| | 1 ppm | | | |
|---|---|---|---|---|
| **Injection No.** | **Intraday Precision** | | **Interday Precision** | |
| | **Area** | **% Assay** | **Area** | **% Assay** |
| 1 | 12541 | 100,02 | 12595 | 100,45 |
| 2 | 12553 | 100,12 | 12602 | 100,51 |
| 3 | 12534 | 99,97 | 12517 | 99,83 |
| 4 | 12533 | 99,96 | 12593 | 100,44 |
| 5 | 12529 | 99,93 | 12475 | 99,50 |
| Average | 12538,0 | 100,00 | 12556 | 100,15 |
| Std. Dev | 9,43 | 0,08 | 57,20 | 0,46 |
| % RSD | 0,08 | 0,08 | 0,46 | 0,41 |

| 4 ppm | | | | |
|---|---|---|---|---|
| **Injection No.** | **Intraday Precision** | | **Interday Precision** | |
| | **Area** | **% Assay** | **Area** | **% Assay** |
| 1 | 71070 | 100,01 | 71071 | 100,01 |
| 2 | 71028 | 99,95 | 71083 | 100,03 |
| 3 | 71052 | 99,98 | 71014 | 99,93 |
| 4 | 71109 | 100,06 | 71023 | 99,94 |
| 5 | 71066 | 100,00 | 70089 | 98,63 |
| Average | 71065,00 | 100,00 | 70856 | 99,71 |
| Std. Dev | 29,58 | 0,04 | 429,80 | 0,60 |
| % RSD | 0,04 | 0,04 | 0,61 | 0,54 |

| 10 ppm | | | | |
|---|---|---|---|---|
| **Injection No.** | **Intraday Precision** | | **Interday Precision** | |
| | **Area** | **% Assay** | **Area** | **% Assay** |
| 1 | 189843 | 100,02 | 189511 | 99,84 |
| 2 | 189873 | 100,03 | 189983 | 100,09 |
| 3 | 189822 | 100,01 | 189594 | 99,89 |
| 4 | 189873 | 100,03 | 189974 | 100,09 |
| 5 | 189644 | 99,91 | 189587 | 99,88 |
| Average | 189811,00 | 100,00 | 189730 | 99,96 |
| Std. Dev | 95,81 | 0,05 | 229,37 | 0,12 |
| % RSD | 0,05 | 0,05 | 0,12 | 0,11 |

### 3.6 Accuracy Study

A known amount of standard was added to the previously analyzed samples. (80%, 100% and 120%). The amount of recovery was calculated for favipiravir at these three concentrations. Table 3 summarizes the recovery information. In all analyses, RSD values were determined to be less than 2%. As a result, the approach is certain to be unaffected by excipients in pharmaceutical formulations.

### 3.7 Robustness

According to the analysis results, it was seen that the mobile phase flow rate and content had little effect on the chromatographic data of FVP. Changes in flow rate and acetonitrile content had little effect on retention time. The method did not alter significantly when the column temperature was changed. Table 4 shows the findings of this study, represented as a % RSD.

**Table 3. Recovery data**

| Spiked Level | Amount added ($\mu g\ mL^{-1}$) | Amount recovered ($\mu g\ mL^{-1}$) | Recovery (%) | Average (%) | S.D. | RSD (%) |
|---|---|---|---|---|---|---|
| **80%** | 4 | 3,97 | 99,25 | 99,96 | 0,901 | 0,902 |
| | 4 | 3,95 | 98,75 | | | |
| | 4 | 3,90 | 97,5 | | | |
| **100%** | 5 | 5,01 | 100,2 | 99,93 | 0,503 | 0,504 |
| | 5 | 4,98 | 99,6 | | | |
| | 5 | 4,96 | 99,2 | | | |
| **120%** | 6 | 5,89 | 98,2 | 99,75 | 0,585 | 0,587 |
| | 6 | 5,93 | 98,8 | | | |
| | 6 | 5,96 | 99,3 | | | |

**Table 4. Robustness data**

| Condition | Variation | Assay % | SD | RSD % |
|---|---|---|---|---|
| Mobile phase flow rate (0.8 mL min$^{-1}$) | 0.9 mL min$^{-1}$ | 99.86 | 0.60 | 0.60 |
| | 0.7 mL min$^{-1}$ | 99.94 | 0.62 | 0.62 |
| Methanol ratio in mobile phase (20 %) | 19 % | 100.12 | 0.67 | 0.67 |
| | 21 % | 99.96 | 0.71 | 0.71 |
| Column temperature (40 $^0$C) | 38 $^0$C | 99.96 | 0.34 | 0.34 |
| | 42 $^0$C | 100.05 | 0.32 | 0.32 |

## 3.8 System Suitability

In the performance evaluation of the method, the suitability parameters of the system were evaluated. Tailing factor 1.1, retention time 1.155 min and number of theoretical plate 5293 were found. These values found were at acceptable levels.

## 3.9 Solution Stability

Over the course of a 24-hour period, stability of the reference standard solutions was examined. For this purpose, standard solutions were injected into the UPLC system with 8-hour periods and the retention time and peak area were recorded. Table 5 shows the results of the stability study. The R.S.D.% was determined as 0.323 for peak area and 0.115% for retention time. No significant changes in the concentration of the active pharmaceutical ingredient in the standard solution were observed.

## 3.10 Application of the Method to the Marketed Tablets

FVP in pharmaceutical formulations has been effectively determined using the established and verified method. Table 6 shows the results of an analysis of a marketed favipiravir tablet. The acquired results are closely connected to the amount specified on the pill labels. This demonstrates the utility of the content evaluation method.

## 3.11 Degredation Study

Decomposition products study was evaluated by applying soft and hard conditions. Decomposition studies; It was carried out under acidic, basic, oxidative, UV light and thermal conditions. The stock standard solution was diluted with 1 N HCl, 1 N NaOH, 30% $H_2O_2$ solutions to 10 ppm concentration. In UV light and thermal state stress studies, the stock standard solution was diluted up to 10 ppm with ultrapure water. In acidic, basic and oxidative studies, the prepared standard solution was kept in an oven at 80 °C for 30 minutes. UV light study was performed by exposing the standard solution to UV light at 254 nm wavelength for 6 and 24 hours at room temperature. Thermal decomposition was completed by waiting in the oven at 100 °C for 6 and 24 hours. In the thermal degradation test, the standard solution was kept in an oven at 100 °C for 6 and 24 hours. The results of the degradation studies are given in Table 7 and Fig. 9. While favipiravir was unstable in acidic, basic and oxidative conditions, it remained stable in other conditions.

**Table 5. Standard solution stability (10 µg mL$^{-1}$)**

| Time, hours | Peak area | Mean | SD | RSD % | Retention time (min) | Mean | SD | RSD % |
|---|---|---|---|---|---|---|---|---|
| 8 | 190583 | 190584,6 | 1,69 | 0,0009 | 1,155 | 1,156 | 0,0012 | 0,108 |
| | 190584 | | | | 1,156 | | | |
| | 190587 | | | | 1,158 | | | |
| 16 | 190588 | 190585,6 | 2,05 | 0,0011 | 1,154 | 1,154 | 0,0008 | 0,071 |
| | 190583 | | | | 1,153 | | | |
| | 190586 | | | | 1,155 | | | |
| 24 | 190582 | 190584 | 1,63 | 0,0008 | 1,156 | 1,155 | 0,0005 | 0,041 |
| | 190586 | | | | 1,155 | | | |
| | 190584 | | | | 1,155 | | | |

**Table 6. Method application results**

| Formulation | Label claim (mg) | Amount of drug (mg) | % Assay ± SD |
|---|---|---|---|
| Favira tablet | 200 mg | 200.35 mg | 100.18 ± 2.05 |

**Table 7. Degradation products under stressed conditions**

| Forced Conditions | Degradation Products m/z |
|---|---|
| 0.1 N HCI | 125,0-112,9 |
| 1 N HCI | 125,0-110,9-96,9-78,9 |
| 0.1 N NaOH | 146,9-124,8-112,9-93,0-78,9 |
| 1 N NaOH | 146,9-125,0-112,9-102,9-79,0-45,0 |
| 3% $H_2O_2$ | 130,9-112,9 |
| 30% $H_2O_2$ | 131,0-124,9-112,9-96,9-86,9 |
| 6 HOUR UV | 124,9-112,9-96,9 |
| 24 HOUR UV | 125,0-113,0-96,9 |
| 6 HOUR THERMAL | 113,0 |
| 24 HOUR THERMAL | 113,0 |

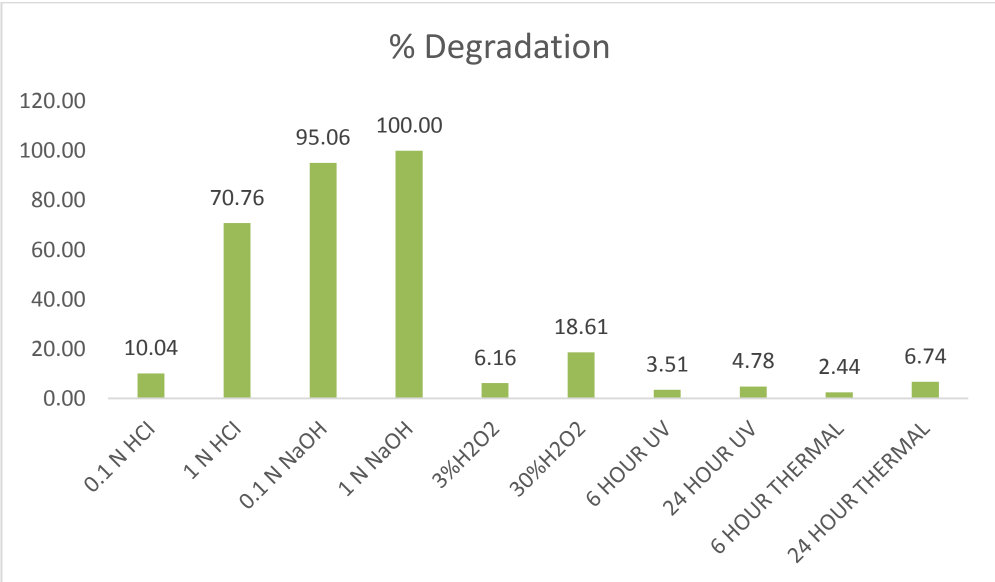


**Fig. 9. Stability profiles under forced conditions**

## 4. CONCLUSION

The developed UPLC method is a fast, reliable and robust method for medical and chemical use. It differs from other studies in the literature with its speed and simplicity. Degradation studies are important for chemical studies, drug production techniques and processes, and further studies, as they show the conditions under which the active substance remains stable and degrades. In this study, the active substance was exposed to different stress conditions and under which conditions it remained stable and under which conditions it degraded was examined. As a result of the decomposition studies, it was observed that the active substance was completely decomposed in the basic conditions and to a large extent in the acidic conditions. The study conducted in terms of drug production, packaging and storage conditions has been presented to the literature as a fast, robust and reliable analysis method.

## DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

## CONSENT

It is not applicable.

## ETHICAL APPROVAL

It is not applicable.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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