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In vitro evaluation and comparison of dissolution profiles for five brands of ciprofloxacin hydrochloride tablets

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ABSTRACT
In vivo oral bioavailability can be predicted by dissolution, a key quality control parameter. The dissolution test is used to evaluate and compare dissolution profiles and establish similarities between pharmaceutical forms. The aim of this study is to evaluate and compare the dissolution profiles of five brands of ciprofloxacin hydrochloride 750 mg tablets available in Al-Bayda City, Libya. The dissolution test was performed using a USP type 2 apparatus at 50 rpm with 900 mL of 0.01N hydrochloric acid at 37.0 ± 0.5 °C for 30 minutes. The dissolution study was performed as per United States Pharmacopeia, and the dissolution profiles were compared by ANOVA-based methods, model-dependent approaches, and model-independent approaches. The result of the in vitro dissolution test showed that four of the five tested brands passed the test and went on to release in 30 minutes not less than 80% of the labeled amount of drug. It also indicated that the Cipro-III brand failed to release 80% of the labeled amount of drug in 30 minutes and thus did not comply with the dissolution test specification. ANOVA statistical analysis of the dissolution profiles showed a significant difference (*P*-value < 0.05) between the dissolution profiles of all brands. Tukey's test and model-independent method showed that the dissolution profiles of brands Cipro-I and Cipro-II were similar, allowing them to be used interchangeably, and the differences in dissolution profiles of the remaining tested brands indicated that they could not be used interchangeably. Drug release from five tested brands fitted best to the Weibull kinetic model.

Keywords: Ciprofloxacin hydrochloride, dissolution profiles, ANOVA-based methods, model-dependent approaches, and model-independent approaches.

1. INTRODUCTION

Solid dosage forms are recommended for oral administration in clinical practice due to their practical, affordable, and safety. Permeability across the gastrointestinal tract and physiological circumstances pose issues with bioavailability. Because of this, it is crucial to emphasize the role that disintegrating and dissolution tests play in establishing pharmacological equivalence, which is related to the process of absorption of medication from a solid dose form when administered orally, depending on how the chemical ingredient is released from the medication product, the medication's solubilization under physiological circumstances, and the permeability it passes through in the digestive system. Consequentially, the significance of disintegration and dissolution tests importance of the pharmaceutical industry equivalency need to be emphasized [1, 2].

Pharmaceutical products need to have consistent and repeatable quality from batch to batch, and the drugs must be tested during and after manufacturing at different points throughout their shelf life to guarantee quality [3]. As a component of good manufacturing practice, quality control provides guidelines for specifications, sampling, documentation, and dissolution. It also guarantees that all relevant and required tests are conducted and that no product is released for supply or sale until its quality has been thoroughly verified and conforms to criteria [4].

In vitro dissolution testing is critical for developing drug formulations and ensuring quality control. It serves as a primary means to monitor drug product consistency and stability and also provides a fast and cost-effective method to predict a drug formulation's absorption in vivo. Consequently, the quantitative assessment of drug dissolution properties is a topic of significant importance for scientists in the pharmaceutical field [5].

One of the synthetic broad-spectrum bactericidal anti-infective medicines belonging to the fluoroquinolone groups is ciprofloxacin. It has exceptional antibacterial action against a variety of bacteria, including Gram-negative and certain Gram-positive bacteria, Mycoplasma, Chlamydia, and numerous Mycobacterium species [6]. It works by inhibiting DNA gyrase, an enzyme necessary for DNA synthesis and replication. It is licensed to treat 14 different types of infections, the most prevalent of which are lower respiratory infections and infections

of the urinary tract, such as acute simple cystitis and chronic bacterial prostatitis [6,7]. Ciprofloxacin is typically used to treat infections that are resistant to antibiotics due to its strength, broad-spectrum activity, and overall safety profile [6].

Because of its adaptability in treating a variety of microbiological infection situations, ciprofloxacin hydrochloride tablets have been used more frequently recently [8]. This has made it necessary to assess the quality of the many products that are available on the market. The purpose of this study is to evaluate and compare the in vitro ciprofloxacin dissolution profile of different brands that are marketed in Al-Bayda City, Libya.

2. MATERIALS AND METHODS

2.1. Materials

Five different brands of ciprofloxacin hydrochloride tablets (750 mg) are shown in Table 1 and were randomly collected and purchased from pharmacies in Al-Bayda City, Libya. Each brand included in the research was within its shelf life at the time of the study, ciprofloxacin standard (Sigma-Aldrich, USA), hydrochloric acid (Riedel-deHaën, Germany), and other reagents and chemicals utilized were of analytical grade.

Table 1: General Features of Ciprofloxacin Tablets of Different Brands (750 mg)

S.No.	Brand code	Name of company	Country of origin	Batch No.	Expiry date
1	Cipro-I	Bristol Laboratories Ltd	United Kingdom	C1621004Z	6/2025
2	Cipro-II	Fugen UK ltd	United Kingdom	EG145	8/2024
3	Cipro-III	Eipico	Egypt	2210842	11/2025
4	Cipro-IV	Itqan Pharmaceutical Industries	Jordan	0480	8/2024
5	Cipro-V	Laboratories Pharmacare	Tunisie	C5243	9\2024

2.2. Methods

2.2.1. UV Spectrophotometry of Ciprofloxacin

Ciprofloxacin of equal concentration (50 mg %) in 0.01N HCL was scanned spectrophotometrically using a UV spectrophotometer, and the wavelength of maximum absorbance (λ max) was determined. Serial dilutions of Ciprofloxacin (2µg/mL–12µg/mL) were prepared. The absorbance of the prepared serial dilutions was measured spectrophotometrically at the predetermined maximum wavelength of 284 nm. The measured absorbance values were plotted against the corresponding concentrations to obtain a calibration curve.

2.2.2. Dissolution test study

For this study, USP dissolution apparatus II was used**.** One tablet per vessel (6 vessels) for each brand was used to test for dissolution. The dissolving medium, which contained 900 ml of 0.01 N HCl, was kept at 37 ± 0.5 °C. The device's rotating speed was maintained at 50 revolutions per minute. At predetermined intervals of 10, 20, and 30 minutes, a 5 ml sample was withdrawn and replaced with the same volume of completely fresh test media. After filtering the sample, 0.25 mL of the filtrate was withdrawn and added to 25 mL of 0.01 N HCl solution. Using 0.01 N HCl as a blank, the absorbance of the diluted filtrate was measured spectrophotometrically at a wavelength of 284 nm. Using standard ciprofloxacin, the percentage of drug release at each interval was calculated.

2.2.3. Statistical evaluation

R software programs [9] were used for statistical analysis. A *P*-value < 0.05 was considered statistically significant. ANOVA plus post hoc Tukey's test was carried out for comparison of the dissolution profile of ciprofloxacin hydrochloride tablets. The dissolution profile of those tablets was also compared by the model-dependent and model-independent approaches with the kinetic program DDSolver.

This paper presents DDSolver, an adaptable and user-friendly add-in software that accomplishes three main goals: (i) supporting the modeling of dissolution data with a library of forty dissolution models and nonlinear optimization methods; (ii) streamlining the comparison of dissolution profiles through various approaches; and

(iii) speeding calculations, reducing errors made by the user, and providing a convenient way to report dissolution data quickly and easily[5].

3. RESULTS AND DISCUSSIONS

The calibration curve, as shown in Figure 1, for standard ciprofloxacin hydrochloride was constructed to calculate the percentage of drug substances released at 10, 20, and 30 min, giving a correlation coefficient of approximately 0.9995 in the concentration range studied (2 to 12 µg/mL). The representative linear equation was y = 0.0701x + 0.0323.

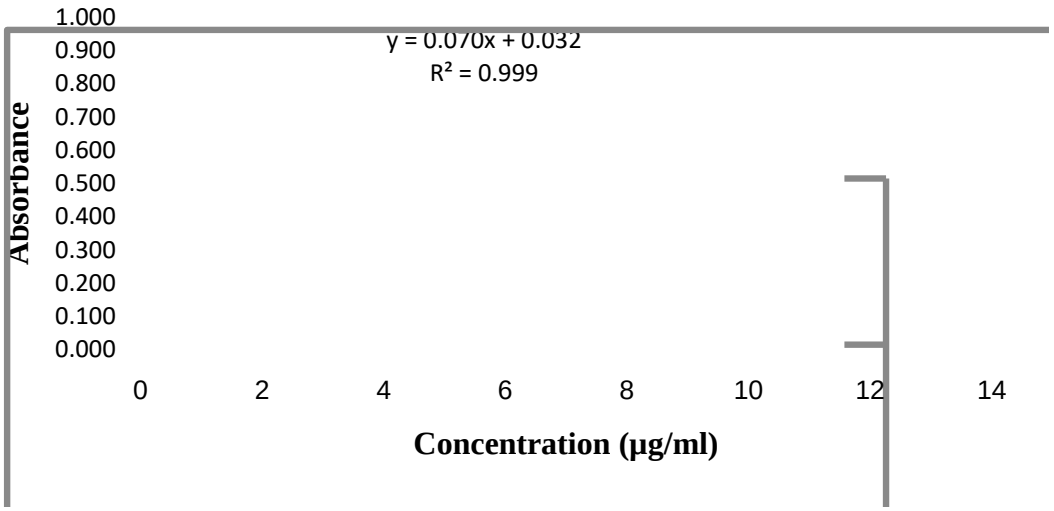

Figure 1: Calibration curve for standard ciprofloxacin hydrochloride.

The dissolution results as the means of percents released versus time and descriptive analyses for commercially available brands of ciprofloxacin tablets are given in Table 2.

Table 2: Dissolution results and descriptive analysis of the tested brands of ciprofloxacin tablets (n = 12)

Time	Product	Mean, %	S. E	95% CI for mean	
				Lower limit	Upper limit
10 min	Cipro-I	70	1.58	66	73
	Cipro-II	75	2.66	69	81
	Cipro-III	20	3.19	13	27
	Cipro-IV	45	2.41	39	50
	Cipro-V	95	1.12	93	98
20 min	Cipro-I	84	1.24	82	87
	Cipro-II	88	1.02	86	90
	Cipro-III	43	3.39	36	51
	Cipro-IV	84	1.59	80	87
	Cipro-V	95	0.88	93	97
30 min	Cipro-I	89	0.65	88	90
	Cipro-II	91	0.80	89	93
	Cipro-III	64	4.35	54	73
	Cipro-IV	90	0.86	88	92
	Cipro-V	97	0.47	96	98

The in vitro dissolution profiles of the ciprofloxacin brands are presented in Figure 2. Each data point represents the mean of twelve measurements for each brand.

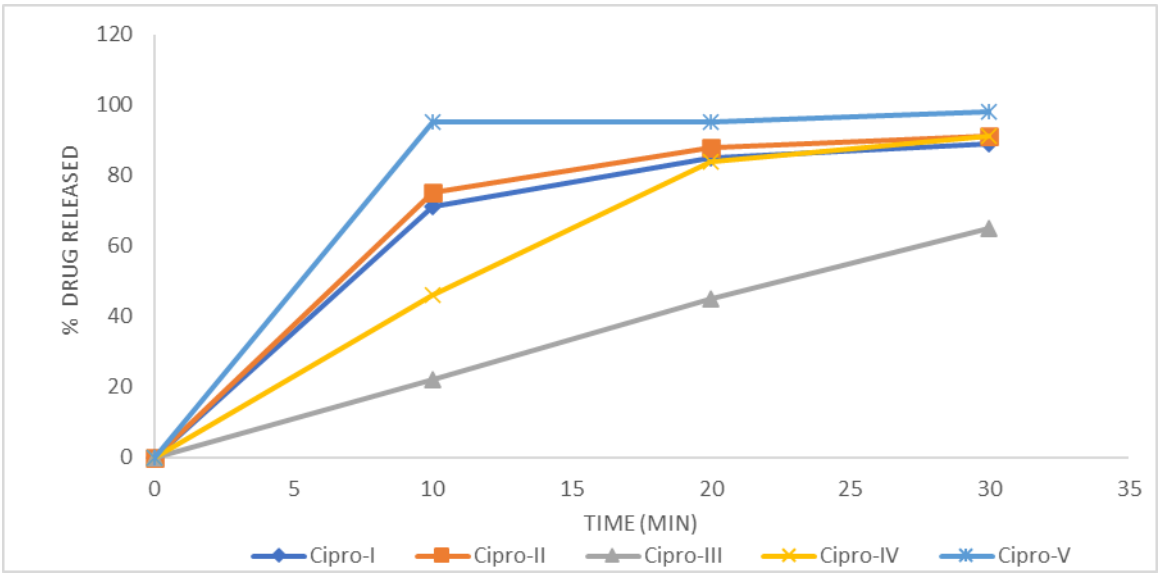

Figure 2: Dissolution profiles of ciprofloxacin 750 mg tablets for five tested brands in 0.01 N HCl. Results were expressed as the mean (n = 12).

To comply with the USP standard, the percentage of ciprofloxacin hydrochloride released at 30 minutes must be at least 80% of the labeled amount. The percentages of drug release from the five tested brands of ciprofloxacin tablets in 30 minutes were in the following order: Cipro-III (65%) > Cipro-I (89%) > Cipro-II and Cipro-IV (91%) > Cipro-V (98%), as shown in Figure 2. All brands complied except Cipro-III, which had 65% at 30 min. In this study, one brand failed to meet the dissolution profile (Cipro-III). Developing formulations and producing finished products, evaluating batch quality, and comparing generic products with their reference products can all be assessed using dissolution profile analysis[10]. ANOVA-based statistical methods, model-dependent methods, and model-independent methods were used to compare dissolution profiles in this study.

3.1. ANOVA-based methods

In order to determine the differences among the five tested brands of ciprofloxacin tablets, the percentage released was tested statistically using ANOVA, and the Tukey test was used to determine where the difference occurred.

Table 3: Results of two-way ANOVA for dissolution test of five brands of ciprofloxacin tablets.

Source of Variation	**df**	**SS**	**MS**	**F**	***P*-value**
Drugs	4	59092	14773	284.29	< 2e-16 ***
Time	2	20565	10283	197.88	< 2e-16 ***
Drugs: Time	8	10015	1252	24.09	< 2e-16 ***
Residuals	165	8574	52		
Signif. codes:	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

According to the results of the statistical evaluation (two-way ANOVA) of the dissolution test given in Table 3, the percents released of drug were found to be significantly different among the five tested brands of ciprofloxacin tablets (*P*-value < 0.05) and at each time level (*P*-value < 0.05), showing a significant (*P*-value < 0.05) time × drug product interaction. When Table. 2 and Figure 3 were examined together, this interaction demonstrated that the mean difference in percent released between two drug brands was not constant at any two points in time, i.e., that the dissolution profiles were not parallel[11]. The results of a one-way ANOVA also showed that the drug products were significantly different in terms of percent released at each time point (*P*-value < 0.05).

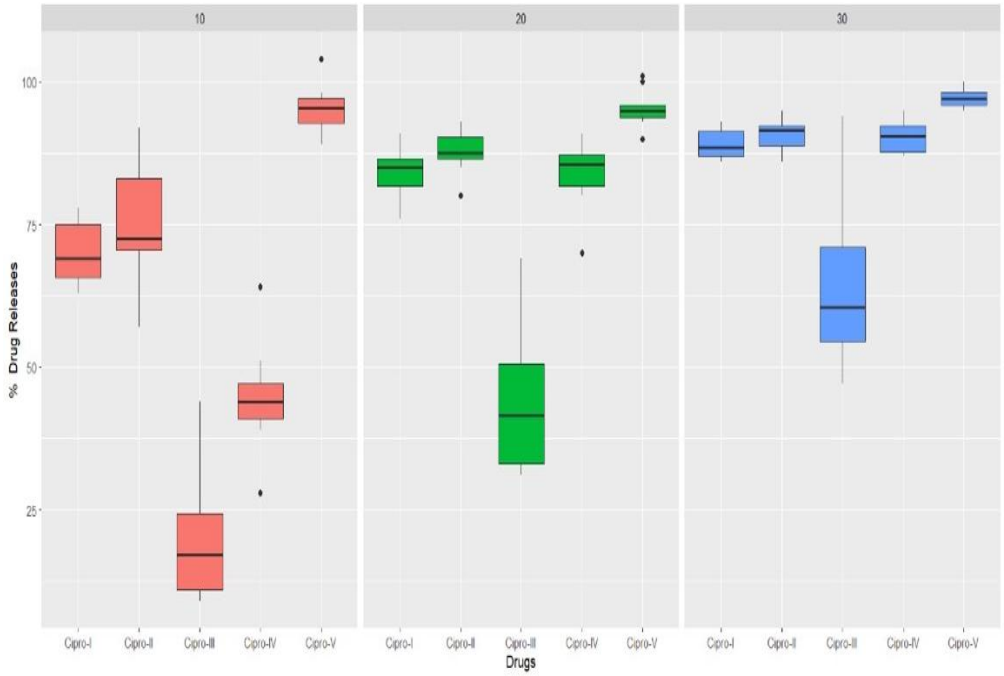

Figure 3: The percentage of drug released from the five tested brands of ciprofloxacin tablets at 10, 20, and 30 minutes (n = 12).

To evaluate the source of the difference among the five tested brands of ciprofloxacin tablets, pairwise comparisons of brands Cipro-I, Cipro-II, Cipro-III, Cipro- IV, and Cipro-V were performed by Tukey multiple comparison of the mean test on the results of the ANOVA. pharmaceutical equivalence means dissolution profiles meet USP dissolution specifications [12].

Table 4: The results of the Tukey test for comparing the dissolution profiles of five tested brands of ciprofloxacin tablets.

Brands	Mean difference (% released)	Significance (*P*-value)	95% CI for mean	
			Lower limit	Upper limit
Cipro-II v/s Cipro-I	3.388889	0.2732320	-1.297472	8.075250
Cipro-III v/s Cipro-I	-38.861111	0.0000000	-43.547472	-34.174750
Cipro-IV v/s Cipro-I	-8.194444	0.0000313	-12.880805	-3.508084
Cipro-V v/s Cipro-I	14.805556	0.0000000	10.119195	19.491916
Cipro-III v/s Cipro-II	-42.250000	0.0000000	-46.936361	-37.563639
Cipro-IV v/s Cipro-II	-11.583333	0.0000000	-16.269694	-6.896972
Cipro-V v/s Cipro-II	11.416667	0.0000000	6.730306	16.103028
Cipro-IV v/s Cipro-III	30.666667	0.0000000	25.980306	35.353028
Cipro-V v/s Cipro-III	53.666667	0.0000000	48.980306	58.353028
Cipro-V v/s Cipro-IV	23.000000	0.0000000	18.313639	27.686361

From Table 4, the results of the Tukey test showed that there was a statistically non-significant difference amongst percent released for brands Cipro-I and Cipro-II (*P*-value > 0.05), while there was a statistically significant difference amongst percent released for the remaining brands. Consequently, as shown in Table 5, it can be inferred that the difference in percent released at 10 min for all brands has a significant difference, except that the percent released for brand Cipro-I is not significantly different from brand Cipro-II (*P*-value > 0.05), while at 20 min the non-significant difference in percent released was observed among the following pairs of tested brands: Cipro-II v/s Cipro-I, Cipro-IV v/s Cipro-I, Cipro IV- v/s Cipro-II, and Cipro V- v/s Cipro-II. At 30 min, there was no significant difference among Cipro-II v/s Cipro-I, Cipro-IV v/s Cipro-I, Cipro-V v/s Cipro-I, Cipro-IV v/s Cipro-II, Cipro-V v/s Cipro-II, and Cipro-V v/s Cipro-IV. It is important to note that the difference identified by ANOVA and the comparison performed by the Tukey test are statistical and not pharmaceutical equivalence. Statistical equivalence means there is no significant difference between products at the 0.05 level.

Table 5: The results of the Tukey test for comparing the dissolution profiles of five tested brands of ciprofloxacin tablets at three time points (10, 20, and 30 min)

Time	Brands	Mean difference (% released)	significance	95% CI for mean	
				Lower limit	Upper limit
10 min	Cipro-II v/s Cipro-I	4.91666667	0.9388977	-5.217411	15.0507444
	Cipro-III v/s Cipro-I	-50.33333333	0.0000000	-60.467411	-40.1992556
	Cipro-IV v/s Cipro-I	-25.41666667	0.0000000	-35.550744	-15.2825890
	Cipro-V v/s Cipro-I	25.16666667	0.0000000	15.032589	35.3007444
	Cipro-III v/s Cipro-II	-55.25000000	0.0000000	-65.384078	-45.1159223
	Cipro-IV v/s Cipro-II	30.33333333	0.0000000	-40.467411	-20.1992556
	Cipro-V v/s Cipro-II	20.25000000	0.0000000	10.115922	30.3840777
	Cipro-IV v/s Cipro-III	24.91666667	0.0000000	14.782589	35.0507444
	Cipro-V v/s Cipro-III	75.50000000	0.0000000	65.365922	85.6340777
	Cipro-V v/s Cipro-IV	50.58333333	0.0000000	40.449256	60.7174110
20 min	Cipro-II v/s Cipro-I	3.41666667	0.9978626	-6.717411	13.5507444
	Cipro-III v/s Cipro-I	-41.00000000	0.0000000	-51.134078	-30.8659223
	Cipro-IV v/s Cipro-I	-0.41666667	1.0000000	-10.550744	9.7174110
	Cipro-V v/s Cipro-I	10.91666667	0.0217285	0.782589	21.0507444
	Cipro-III v/s Cipro-II	-44.41666667	0.0000000	-54.550744	-34.2825890
	Cipro-IV v/s Cipro-II	-3.83333333	0.9931080	-13.967411	6.3007444
	Cipro-V v/s Cipro-II	7.50000000	0.4125251	-2.634078	17.6340777
	Cipro-IV v/s Cipro-III	40.58333333	0.0000000	30.449256	50.7174110
	Cipro-V v/s Cipro-III	51.91666667	0.0000000	41.782589	62.0507444
	Cipro-V v/s Cipro-IV	11.33333333	0.0134994	1.199256	21.4674110
30 min	Cipro-II v/s Cipro-I	1.83333333	0.9999987	-8.300744	11.9674110
	Cipro-III v/s Cipro-I	-25.25000000	0.0000000	-35.384078	-15.1159223
	Cipro-IV v/s Cipro-I	1.25000000	1.0000000	-8.884078	11.3840777
	Cipro-V v/s Cipro-I	8.33333333	0.2408762	-1.800744	18.4674110
	Cipro-III v/s Cipro-II	-27.08333333	0.0000000	-37.217411	-16.9492556
	Cipro-IV v/s Cipro-II	-0.58333333	1.0000000	-10.717411	9.5507444
	Cipro-V v/s Cipro-II	6.50000000	0.6581904	-3.634078	16.6340777
	Cipro-IV v/s Cipro-III	26.50000000	0.0000000	16.365922	36.6340777
	Cipro-V v/s Cipro-III	33.58333333	0.0000000	23.449256	43.7174110
	Cipro-V v/s Cipro-IV	7.08333333	0.5134380	-3.050744	17.2174110

3.2. Model-independent methods

The FDA's industry guides also recommended using F1 and F2 for dissolution profile comparison. According to these guidelines, F1 values up to 15 between 0 and 15 and F2 values larger than 50 between 50 and 100 assure that the two curves are similar or equivalent [13]. Model-independent methods were used to confirm the pharmaceutical interchangeability between different brands[14]. To compare the dissolution profiles of the five tested brands of ciprofloxacin tablets, a model-independent approach of difference factor F1 and similarity factor F2 was employed with the three time points included in the calculations. For the five tested brands, there are ten possible pairings. Brands were compared in pairs, and Table 6 shows the results.

Table 6: The model-independent results for the five tested brands of ciprofloxacin tablets

Brands	Cipro-II v/s Cipro-I	Cipro-III v/s Cipro-I	Cipro-IV v/s Cipro-I	Cipro-V v/s Cipro-I	Cipro-III v/s Cipro-II	Cipro-IV v/s Cipro-II	Cipro-V v/s Cipro-II	Cipro-IV v/s Cipro-III	Cipro-V v/s Cipro-III	Cipro-V v/s Cipro-IV
F1	4.53	47.74	10.70	18.11	50.00	13.78	12.99	72.44	125.98	31.05
F2	69.90	19.88	41.96	39.18	17.88	37.83	44.72	25.05	12.58	26.25

The dissolution profile of Cipro-I using the model-independent approach of F1 and F2 is similar and probably bioequivalent with that of Cipro-II, so they may be used interchangeably, as shown in Table 6. Furthermore, all other brand pairs did not meet the criteria of similarity using the F2 factor. But, by using the F1 difference factors, Cipro-IV can probably be considered bioequivalent to Cipro-I and Cipro-II. Also, Cipro-V is bioequivalent to Cipro-II.

The values of F1 and F2 factors for ten compared pairs of tested brands of ciprofloxacin tablets were calculated from the means of percent released at each time point (Table 2), and the results are listed in Table 7.

Table 7: The model-independent results for the five tested brands of ciprofloxacin tablets at three time points (10, 20, and 30 min)

Brands	Time (min)					
	10		20		30	
	F1	F2	F1	F2	F1	F2
Cipro-II v/s Cipro-I	7.14	64.63	4.76	69.24	2.25	82.53
Cipro-III v/s Cipro-I	71.43	15.05	48.81	19.35	28.09	30.09
Cipro-IV v/s Cipro-I	35.71	30.09	0.00	100.00	1.12	92.47
Cipro-V v/s Cipro-I	35.71	30.09	13.10	47.84	8.99	54.68
Cipro-III v/s Cipro-II	73.33	12.98	51.14	17.33	29.67	28.42
Cipro-IV v/s Cipro-II	40.00	26.13	4.55	69.24	1.10	92.47
Cipro-V v/s Cipro-II	26.67	34.92	7.95	57.53	6.59	60.79
Cipro-IV v/s Cipro-III	125.00	30.09	95.35	19.35	40.63	29.24
Cipro-V v/s Cipro-III	375.00	6.25	120.93	14.20	51.56	24.06
Cipro-V v/s Cipro-IV	111.11	15.05	11.58	47.84	7.22	57.53

As seen in Table 7, the F1 and F2 values for all compared brand pairs changed depending on the three time points for dissolution considered. During the intervals of 10, 20, and 30 min, F1 values were decreased while F2 values were increased. For the Cipro-II v/s Cipro-I pair, although the similarity degree changed in the same way, F1 values were smaller than 15 and F2 values were greater than 50, indicating that the dissolution profile of Cipro-II was similar to the profile of Cipro-I and so may be used interchangeably. Cipro-III has the dissolution profile the furthest away from the profiles of Cipro-I, Cipro-II, Cipro-IV, and Cipro-V at the first 10 minutes, indicating a greater difference in dissolution up to this time point. When F1 and F2 were calculated with the dissolution data up to 20 and 30 min, the difference decreased, and so they may not be used interchangeably. For Cipro-IV v/s Cipro-I, Cipro-IV v/s Cipro-II, and Cipro-V v/s Cipro-II pairs, the dissolution profiles moved away at earlier time points and were closer at later time points. Consequently, the dissolution profiles of Cipro-IV v/s Cipro-I, Cipro-IV v/s Cipro-II, and Cipro-V v/s Cipro-II were found to be different for the dissolution up to 10 min (F2 = 30.09, F2 = 26.13, and F2 = 34.92, respectively), while they were found to be similar for the dissolution up to 20 and 30 min (F2 = 100 and 92.47, F2 = 69.24 and 92.47, F2 = 57.53 and 60.79, respectively). The change in F1 values depending on the three points for dissolution was pronounced as that for the F2 values for the Cipro-IV v/s Cipro-I, Cipro-IV v/s Cipro-II, and Cipro-V v/s Cipro-II pairs. F1 values were greater than 15 for the dissolution up to 10 min (F1 = 35.71, F1 = 40.00, and F1 = 26.67, respectively), while they were found to be smaller than 15 for the dissolution up to 20 and 30 min (F1 = 0.00 and 1.12, F1 = 4.55 and 1.10, and F1 = 7.95 and 6.59, respectively). This indicated that these brand pairs had identical dissolution profiles at a later time point (20 and 30 min).

For Cipro-V v/s Cipro-I and Cipro-V v/s Cipro-IV pairs, the F1 values were greater than 15 for the dissolution up to 10 min (F1 = 35.7 and F1 = 111.11, respectively), while they were found to be smaller than 15 for the dissolution up to 20 and 30 min (F1 = 13.10 and 8.99, F1 = 11.58 and 7.22, respectively). The result of F1 indicated that these brand pairs had identical dissolution profiles at a later time point (20 and 30 min). But the result of F2 indicated that Cipro-V v/s Cipro-I and Cipro-V v/s Cipro-IV pairs had identical dissolution profiles at a later time point (30 min) and were found to be different for the dissolution up to 10 and 20 min (F2 = 30.09 and 47.84, F2 = 15.05 and 47.84, respectively), while they were found to be similar for the dissolution up to 30 min (F2 = 54.68, F2 = 57.53, respectively).

The comparison of fit factors (F1 and F2) does not show intra-batch variability because calculations are based on mean values. Furthermore, it appears to be insensitive to dissolution profile forms and does not consider unequal sampling time points[15]. When identifying differences between dissolution curves, the similarity factor (F2) is more sensitive than the difference factor (F1), and the fit factor values are dependent upon the number of selected sample time points[14]. It is considered that the similarity and dissimilarity between dissolution profiles shown by using Tukey's test of multiple comparison are more sensitive compared to the limit values of F1 and F2 [16].

3.3. Model-dependent methods

Using mathematical equations that characterize the release profile as a function of certain parameters associated with pharmaceutical formulations makes the quantitative interpretation of the dissolution data easier [11]. Drug release from dosage forms might require several steps that are prompted by various physical or chemical processes, making it challenging to develop a mathematical model that accurately describes this process[14]. A number of model-dependent approaches were used to analyze every dissolution profile. It has been suggested

that model-dependent approaches be used mainly in the case of several time points [11,14]. The highest correlation coefficient values (r^2) were the best parameter to employ in the selection of the best models available for comparison after fitting these models to the individual unit dissolution data.

Table 8: The correlation coefficients (r^2) of fitting dissolution data of five tested brands of ciprofloxacin tablets using a model-dependent approach

Brands	Zero-Order Model	First-Order Model	Higuchi Model	Korsmeyer-Peppas Model	Hixson-Crowell Model	Weibull Model
Cipro-I	-7.5615	0.5664	-0.4173	0.9779	-0.1431	0.9962
Cipro-II	-13.0836	0.5031	-1.7683	0.9514	-0.1822	0.9962
Cipro-III	0.9981	0.9371	0.7702	0.9989	0.9661	0.9962
Cipro-IV	0.5666	0.9166	0.8755	0.8899	0.9508	0.9962
Cipro-V	-1409.2679	-10.7056	-427.7283	0.6132	-78.2167	0.9962

Based on the correlation coefficients acquired by the model-dependent approaches in Table 8, it has been shown that the Weibull model with a higher r^2-value was that which fit best to the dissolution data of Cipro-I, Cipro-II, Cipro-III, and Cipro-IV, while the second best was Korsmeyer Peppass, which provided the best fitting model for Cipro-V. Among other models, the Weibull model is the preferred model to describe the dissolution curve in terms of shape and scale parameters[11].

4. CONCLUSION

According to the results of the present study, all tested brands of ciprofloxacin hydrochloride tablets met the criteria established in the USP pharmacopoeia official monograph for in vitro dissolution testing except for one (Brand Cipro-III). The dissolution profiles were compared with ANOVA-based methods with Tukey's test, model-dependent approaches, and model-independent approaches, showing that brands Cipro-I and Cipro-II met the acceptance criteria and were bioequivalent. The remaining brands are dissimilar and may not be considered bioequivalent, which results in interchangeability issues. The Weibull model provided the best adjustment for all brands Cipro-I, Cipro-II, Cipro-III, and Cipro-IV, while the Korsmeyer Peppass model provided the best fitting model for brand Cipro-V with the highest r^2-value. A well-constructed dissolution test should be carried out by researchers and the company as confirmation of an in vitro bioequivalence study supported by in vivo bioavailability data.

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