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Biopharmaceutical Quality Assessment of Multisource Ciprofloxacin 500 mg Tablets Circulating in the Federal Capital Territory, Nigeria

Durojaye Aishat Bisoye[1], Galadima Isa Hayatu[2], Omachoko Sunday Odoma[3], Isaac Johnson Ajeh[1,*]

[1]Drug Manufacturing Unit, Department of Pharmaceutical Technology and Raw Materials Development, National Institute for Pharmaceutical Research and Development (NIPRD), Abuja, Nigeria.
[2]Department of Medicinal Chemistry and Quality Control, National Institute for Pharmaceutical Research and Development (NIPRD), Abuja, Nigeria.
[3]Department of Pharmacy, Nisa Premier Hospital, Abuja, Nigeria

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*Corresponding Author:
Isaac Johnson Ajeh,
Email: ajeh.johnson@niprd.gov.ng
johnsonisaac11@yahoo.com
Tel: +234 803 918 5040

ABSTRACT

Background: The quality of ciprofloxacin generics in Nigeria is a concern due to the potential for therapeutic failure and antimicrobial resistance.

Objectives: This study evaluated the pharmaceutical equivalence of nineteen (19) brands of ciprofloxacin, 500 mg tablets marketed within the Federal Capital Territory (FCT), Abuja, Nigeria. The samples were purposively collected from registered retail community pharmacies following WHO guidelines for medicine quality surveillance.

Methodology: Methodology involved assessing physicochemical properties, dissolution profiles, similarity factor (f2), dissimilarity factor (f1), dissolution efficiency (DE), and mean dissolution time (MDT).

Results: While all brands met pharmacopeial standards for an immediate-release solid oral dosage form, only one brand met both f1 and f2 similarity requirements. Although most brands achieved DE values > 80 %

Conclusions: While many generics eventually release their full drug content, they do not do so at a rate similar to the reference brand, which is critical for concentration-dependent antibiotics. Similarity and dissimilarity factors can be useful for regulatory purposes; they may not provide the same level of insight as mean dissolution time and dissolution efficiency.

1. Introduction

Infectious diseases impose a substantial burden on Nigeria's healthcare system, accounting for a significant portion of morbidity and mortality[1] Ciprofloxacin, a second-generation fluoroquinolone, is one of the most popularly prescribed and used antibiotics in Nigeria due to its broad-spectrum activity against Gram-positive and Gram-negative organisms[2]. It is widely used in the treatment of urinary tract infections (UTI), respiratory tract infections, gastrointestinal infections (GIT), and other bacterial diseases[2]. The availability and affordability of ciprofloxacin make it a popular choice in both public and private health facilities[3].

The quality of medicines available in developing countries like Nigeria is still an ongoing and significant concern. Substandard, falsified, or poor-quality antibiotics can lead to treatment failures, contribute to drug resistance, and increase illness and death rates[1]. These quality issues

undermine confidence in generic medicines, which are often more affordable and critical for ensuring equitable access to healthcare in resource-constrained settings.

To assess the quality and therapeutic interchangeability of generic drugs, in vitro dissolution testing is a widely accepted method. Dissolution profiles provide insights into the rate and extent of drug release, which are critical for predicting bioavailability and bioequivalence[4]. Key metrics such as the dissimilarity factor (f1), similarity factor (f2), mean dissolution time (MDT), and dissolution efficiency (DE) are used to compare generic and innovator products, with f1 and f2 values of 0-15 and 50-100 respectively indicating similarity in release profiles[4] These parameters are essential for ensuring that generic drugs perform comparably to their reference counterparts, supporting safe generic substitution in clinical practice[5]. In Nigeria, where multiple ciprofloxacin brands are marketed, assessing these parameters is crucial to verify quality and guide regulatory decisions.

This study aims to evaluate the physicochemical and biopharmaceutical properties of ciprofloxacin brands marketed in Abuja, Nigeria, to determine their similarity and compliance with pharmacopoeia standards. By comparing the quality attributes of generic and innovator products, this study seeks to provide evidence to support regulatory oversight and promote confidence in generic substitution. The findings will contribute to evidence-based interventions to strengthen pharmaceutical quality assurance in Nigeria, ensuring access to safe and effective antimicrobial treatments.

2. Methodology

Materials

For each of the nineteen (19) brands, three blister packs (30 tablets per brand) of ciprofloxacin tablets (500 mg) were purchased from ten (10) different licensed retail community pharmacies strategically located across the major area councils of the Federal Capital Territory (FCT), including Abuja Municipal (AMAC), Gwagwalada, and Bwari. This spread was intended to capture the variety of generic brands circulating in both the city center and the satellite towns. Brands were coded C1 to C19, with batch numbers, NAFDAC numbers, country of manufacturing, production, and expiration dates recorded (Table 1).

Reagents: Hydrochloric acid (37% purity), BDH, India; Sodium hydroxide pellets (98% purity), BDH, India; Ciprofloxacin reference standard (99.8% purity), Merck, U.S.A; Distilled water (Laboratory grade), freshly prepared.

Methods

Determination of Tablets' Uniformity of Weight

Twenty (20) tablets from each batch were randomly sampled and individually weighed using a Metler Toledo AB54 analytical balance. The weight variation (WV) was calculated by comparing each tablet's weight to the average weight of the 20 tablets[6].

Determination of Tablet Thickness and Diameter

The thickness and diameter of an average of 6 tablets from each batch were measured using a digital micrometer screw gauge (Mitutoyo IDC-1012EB, Japan) to determine average dimension[5]

Determination of Tablets Crushing Strength

Six tablets from each batch were randomly chosen for hardness testing using an Erweka hardness tester (D-6072, Germany), which applied increasing force until the tablet fractured[7].

Percentage Friability Testing

Ten randomly selected tablets from each batch were tested for friability using an Erweka friabilator (Type TA, Germany), rotating at 25 rpm for 4 minutes, and the percent friability (F) was then calculated as:

$$f = W1 - W2\ x\ 100/W1$$

Where W1 is the tablet's initial weight, and W2 is the weight of tablets after friability[7].

Assay Test Evaluation

A 100 mg reference ciprofloxacin powder was dissolved in 100 mL of 0.01 N NaOH to obtain a stock solution of 1 mg/mL. From the stock solution, a serial dilution from 5 µg/mL to 50 µg/mL was prepared, and the absorbance was measured at 275 nm. A standard calibration plot was obtained by plotting a graph of absorbance against concentration (Fig. 1).

Twenty tablets from each brand were powdered, and an amount equivalent to 100 mg of ciprofloxacin was dissolved in 50 mL of 0.1N NaOH. The mixture was shaken for 2 minutes and then diluted to 100 mL. After filtration, the absorbance of each sample was measured at 275 nm using a UV spectrophotometer. These absorbance values were extrapolated from the standard calibration equation to obtain the respective concentrations. The percentage recoveries were obtained by comparing the extrapolated concentration with the label claim[2].

Disintegration Time Determination

The disintegration test was conducted using a BJ-III Disintegration tester (Biobase, China), where six tablets from each brand were placed in separate basket compartments and subjected to continuous immersion and lifting in distilled water at 37 ºC. The time taken for each tablet to disintegrate and pass through the basket mesh was recorded, and the average disintegration time noted[8].

Drug Dissolution Testing Procedure

A USP Type II dissolution tester (RC-6, China) was used to evaluate the dissolution profiles of ciprofloxacin tablets in 900 mL, 0.1N HCl at 37 ºC at 50 rpm. A tablet from a batch was placed in each of the vessels. An aliquot of 10 mL was withdrawn at intervals from each vessel (and replaced with the same volume) at a point halfway between the surface of the media and the top of the rotating paddle and not less than 10 mm from the wall of the vessel. The aliquot was filtered with a 0.45 µm filter paper, and the absorbance was read at 275 nm using a UV/vis spectrophotometer (Cary-60, Agilent Technologies) to extrapolate the percentage dissolution of the ciprofloxacin tablet[8].

Dissimilarity, Similarity, Dissolution Efficiency, and Mean Dissolution Time Evaluation

To compare dissolution profiles, the dissimilarity factor (f1) and similarity factor (f2) were used to evaluate differences and similarities between the generic and reference brand (C1). Dissolution efficiencies (DE) and mean dissolution times (MDT) were also determined for each batch[5].

Dissimilarity factor (f1):

$$f_1 = \{[\sum_{t=1}^{n} |R_t - T_t|] \Big/ [\sum_{t=1}^{n} R_t]\} \times 1$$

Similarity factor (f2):

$$f_2 = 50 \cdot \log\{[1 + \frac{1}{n}\sum_{t=1}^{n}(R_t - T_t)^2]^{-0.5} \times 100\}$$

Dissolution Efficiency (DE):

$$DE = \frac{\int_{t_1}^{t_2} y \cdot dt}{y_{100} \times (t_2 - t_1)} \times 100$$

Mean Dissolution Time (MDT)

$$MDT = \sum_{j=i}^{n} tj\Delta Mj / \sum_{j=i}^{n} \Delta Mj$$

Where R_t is the percentage of dissolved reference brand at a given time t, T_t is the percentage of the dissolved generic product, n is the number of time point, y is the percentage of dissolved product, dt is the area under the dissolution curve between time point t1 and t2 expressed as a percentage of the curve at maximum dissolution, y_{100}, over the same time period[5].

3. Results

The physicochemical properties of the 19 ciprofloxacin brands are presented in Table 2. All brands met the pharmacopeial requirements for weight uniformity, with relative standard deviation (RSD) values ranging from 0.08% to 0.21%. The diameter and thickness of the tablets were consistent across brands, with minimal deviations. Friability values were below 1%, indicating that the tablets were robust enough to withstand handling and transportation.

The disintegration times of the tablets are presented in Table 2. All brands met the pharmacopeial requirement for disintegration, with most brands disintegrating within 7 minutes. However, some brands (C4, C13, C14, C15, and C18) disintegrated at a slower rate, ranging from 11 to 14.6 minutes.

The assay values for the 19 brands are presented in Table 2. All brands met the pharmacopeial requirement for assayed drug content, with values ranging from 95.0% to 102.1%.

The cumulative drug release profiles of the 19 brands are presented in Figures 2-3. The reference product (C1) showed rapid release, with 42% released at 5 minutes and nearly complete release (101%) at 30 minutes. Brands C7, C8, and C12 demonstrated similar rapid release patterns, while brands C2, C3, C4, C5, and C6 exhibited slower dissolution, releasing only 39-60% of their content within 10-20 minutes. Ultimately, all brands met the compendial specification for the dissolution of an immediate-release formulation.

The choice of C1 as the comparator brand was justified by its robust physicochemical profile and its role as a benchmark for high-quality imported generics in the Nigerian market, providing a rigorous standard for the evaluation of f1 and f2 factors.

The similarity factor (f2) and dissimilarity factor (f1) values

are presented in Table 3. Only brand C8 met both f1 and f2 similarity requirements, with an f1 and f2 value of 7 and 54, respectively. Brands C7, C10, C12, and C18 had f1 values ≤15, but their f2 values were below 50.

The dissolution efficiency (DE) and mean dissolution time (MDT) values are presented in Table 3. Brands with rapid cumulative release (C7, C8, C12) had shorter MDT and higher DE values, while those with poor cumulative release (C2, C3, C5, C6) showed longer MDT and lower DE values. Overall, most brands achieved a % DE value greater than 80 %.

Table 1. Sample information for brands of ciprofloxacin tablets assessed

BRANDS	NAFDAC NO.	MAN. DATE	EXP. DATE	BATCH NO	COUNTRY
C1	04-3002	06/2022	05/2027	M2049	Nigeria
C2	NIL	04/2022	03/2025	BAC342	Pakistan
C3	B4-5856	10/2021	10/2024	211021	China
C4	B4-4183	12/2021	11/2024	211201	China
C5	B5-5947	02/2022	12/2025	220218	China
C6	04-6608	03/2022	02/2025	220374	China
C7	04-2307	08/2021	07/2024	E16QP21006	India
C8	04-8805	01/2022	12/2024	A220083	Nigeria
C9	04-7022	02/2023	02/2026	CV13	Nigeria
C10	04-6340	03/2021	02/2024	PL21021	India
C11	04-4061	10/2021	09/2025	ECQT-027	India
C12	B4-0418	12/2021	11/2024	TE1312	India
C13	B4-3233	02/2022	01/2025	22140205	Nigeria
C14	B4-4695	10/2022	09/2025	ACA/22/002	Nigeria
C15	04-0723	02/2022	01/2025	C012009	India
C16	B4-5916	03/2021	02/2024	VP13107	India
C17	B4-1405	01/2023	12/2027	01A	Nigeria
C18	A4-1838	03/2022	02/2025	C012022	Nigeria
C19	A4-0327	09/2022	03/2025	2208	Nigeria

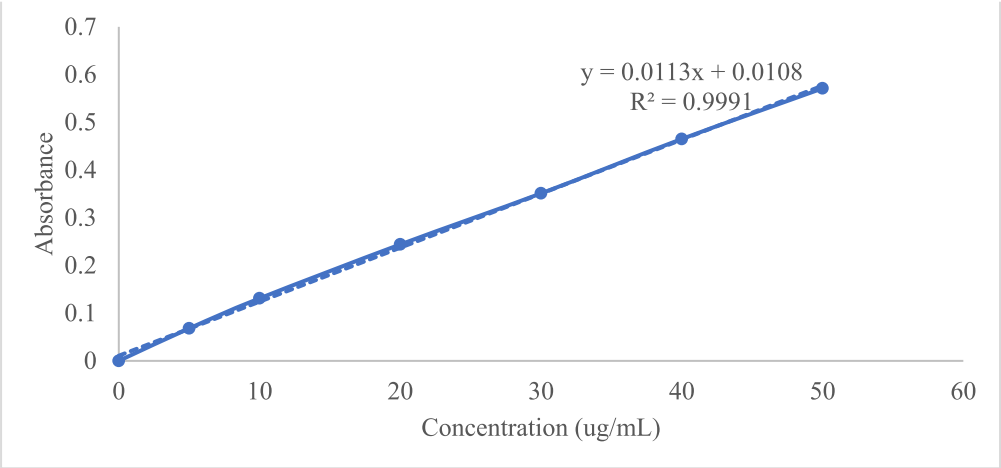

Figure 1: Calibration plot for ciprofloxacin HCl in 0.01N NaOH

Table 2. Thickness (T), diameter (D), hardness (H), friability (F), weight variation (WV), disintegration time (DT) and assay (A) values for brands of ciprofloxacin assessed

	T (mm)	D (mm)	H (KgF)	F (%)	WV (%RSD)	DT (min)	A (%)
C1	5.67(0.01)	8.16(0.01)	14.73(1.41)	0.05	0.15	1.58(0.01)	98.8
C2	5.94(0.02)	8.02(0.02)	13.67(0.58)	0.06	0.15	2.20(2.01)	95.1
C3	5.52(0.10)	8.13(0.01)	10.43(0.67)	0.03	0.13	3.29(1.52)	97.5
C4	5.80(0.06)	8.17(0.01)	11.6(1.97)	0.03	0.15	12.01(3.22)	95.0
C5	6.07(0.14)	9.16(0.02)	10.07(2.14)	0.01	0.15	8.37(0.94)	99.0
C6	5.88(0.04)	7.98(1.84)	18.20(2.50)	0.12	0.15	5.25(3.30)	100.3
C7	5.45(0.05)	12.17(0.08)	18.20(2.50)	0.03	0.12	2.27(1.11)	100.7
C8	4.67(0.10)	9.12(0.01)	15.13(0.23)	0.03	0.15	3.40(5.51)	95.4
C9	5.99(0.02)	9.25(0.03)	1.37(1.53)	1.14	0.14	2.13(2.28)	98.3
C10	5.94(0.04)	9.19(0.03)	6.87(4.75)	0.01	0.15	7.10(3.22)	96.0
C11	6.45(0.12)	9.25(0.03)	9.33(1.50)	0.08	0.21	6.40(0.66)	95.1
C12	5.96(0.10)	8.21(0.01)	3.80(2.14)	0.07	0.12	2.05(2.02)	98.1
C13	4.29(0.06)	9.38(0.45)	5.60(1.97)	0.10	0.08	11.58(1.18)	96.8
C14	4.62(0.05)	9.71(0.04)	14.47(2.20)	0.12	0.18	12.34(3.30)	99.7
C15	6.08(0.06)	7.90(0.10)	19.00(3.46)	0.00	0.16	14.56(0.11)	95.0
C16	5.78(0.08)	8.22(0.02)	3.27(0.71)	0.09	0.13	0.28(0.02)	102.1
C17	5.31(0.21)	8.13(0.04)	20.00(1.00)	0.00	0.16	6.26(3.01)	100.5
C18	5.16(0.03)	9.10(0.05)	16.67(3.51)	0.12	0.14	13.15(3.11)	99.0
C19	6.00(0.05)	9.23(0.11)	14.00(1.00)	0.02	0.19	11.45(2.22)	100.7

Table 3. Similarity factor (f2), dissimilarity factor (f1), dissolution efficiency (DE), and mean dissolution time (MDT) for brands of ciprofloxacin.

BRANDS	f1	f2	MDT (min)	DE (%)
C1			0.12	91
C2	35	31	0.20	50
C3	27	34	0.19	70
C4	39	27	0.28	47
C5	35	29	0.23	49
C6	24	36	0.22	48
C7	10	48	0.10	85
C8	7	54	0.09	96
C9	20	42	0.08	97
C10	15	44	0.07	98
C11	17	43	0.12	91
C12	10	47	0.09	96
C13	19	41	0.06	98
C14	17	42	0.14	82

C15	16	41	0.07	98
C16	16	43	0.13	89
C17	17	45	0.14	87
C18	12	44	0.09	96
C19	18	42	0.06	98

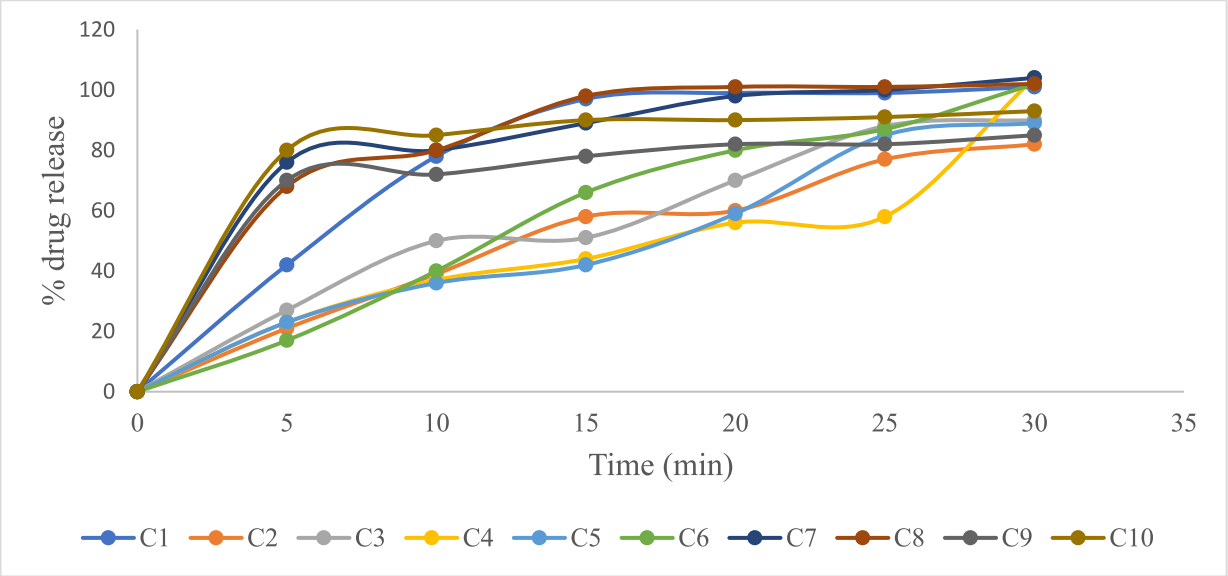

Figure 2: Cumulative drug release of ciprofloxacin tablet brands 1 - 10

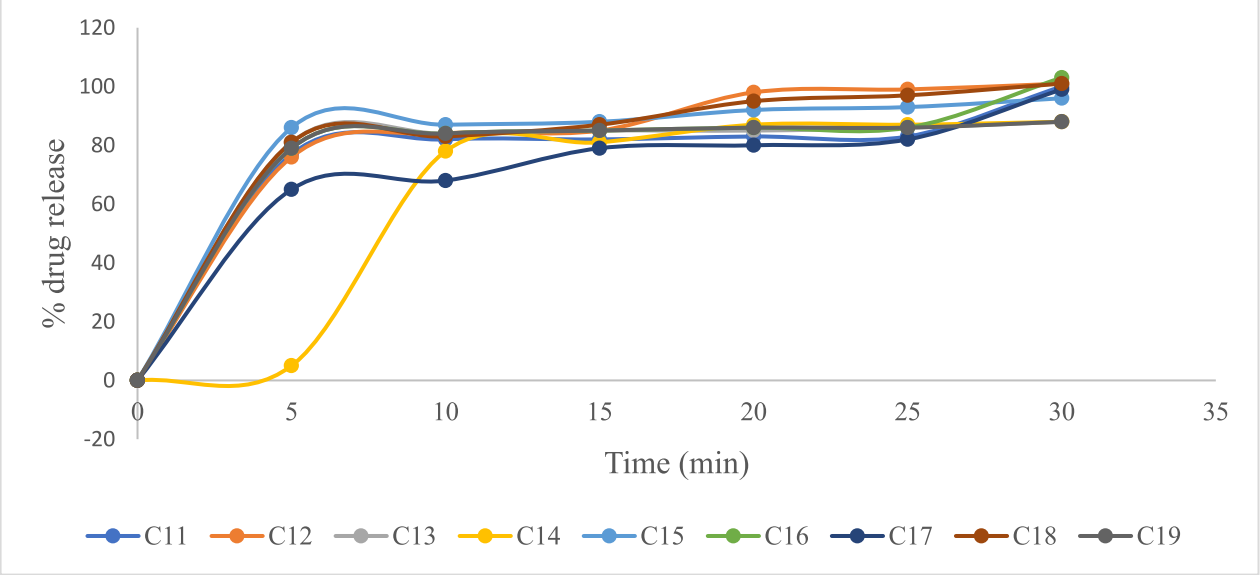

Figure 3: Cumulative drug release of ciprofloxacin tablet brands 11 – 19

4. Discussion

This study assessed the pharmaceutical equivalence of 19 ciprofloxacin brands in Abuja, Nigeria, highlighting the importance of dissolution profiles in ensuring therapeutic effectiveness. Despite meeting official standards, some brands exhibited significantly different dissolution rates, which could impact patient outcomes.

The disparities in dissolution profiles may be considered within the context of the local supply chain. In regions like the FCT, where temperatures frequently exceed 30°C, the integrity of the tablet matrix can be compromised, where chemical bridges are formed between excipients over time (cross-linking) if storage conditions are suboptimal. This can turn a fast-dissolving tablet into a slow-dissolving one after just a few months on a pharmacy shelf. Although the pharmacies sampled followed standard storage protocols, the cumulative effect of post-production handling on the biopharmaceutical performance of these generics warrants further investigation[9,10].

Ciprofloxacin can exist in different crystalline forms (polymorphs) or as an amorphous solid. Some polymorphs are more soluble than others. If Brand C1, for instance, uses a different crystal form than C2, their solubility, and thus their dissolution rate, will differ[11].

The choice and concentration of excipients could significantly impact the performance of ciprofloxacin brands. Disintegrants like croscarmellose sodium or sodium starch glycolate facilitate tablet breakdown, but insufficient or low-quality options delay API release. Binders (e.g., PVP or starch) can also hinder performance if overly abundant, creating a dense tablet matrix that is resistant to water[11,12]. Additionally, hydrophobic lubricants like magnesium stearate can slow dissolution if overused, coating drug particles and blocking water penetration[12].

The physical manufacturing process significantly impacts tablet kinetics, even with identical ingredients. High compression pressure during tableting increases hardness and reduces porosity, hindering dissolution medium penetration and increasing MDT[13]. The granulation technique also plays a role; wet granulation can cause case-hardening, slowing API release. Additionally, particle size distribution affects dissolution rate, as smaller particles (larger surface area) dissolve faster according to the Noyes-Whitney equation. Variations in raw API particle size across generics can lead to differing dissolution profiles[11,14].

Regulatory guidelines from the US FDA and WHO emphasize the need for similar dissolution profiles to support pharmaceutical equivalence[3]. DE has been proven to be a robust framework to which drug release profiles could be summarized, facilitating comparisons, and potentially correlating with *in vivo* data, while MDT has helped with identifying optimal dissolution profiles and ensuring batch-to-batch consistency[11,15]. Our findings clearly indicate a correlation between the cumulative drug release, MDT, and DE values of the ciprofloxacin brands. Brands with rapid release demonstrated superior dissolution characteristics, as evidenced by their shorter MDT and higher DE values. These suggest that these brands are more likely to achieve rapid release of the active pharmaceutical ingredients, leading to faster absorption and onset of action, and improved therapeutic efficacy[9,16]. While the f1 and f2 factor indicated that only Brand C8 was statistically similar to the reference, the DE values revealed that 14 out of 19 brands eventually achieved high dissolution efficiency, albeit at different rates (MDT). The apparent disconnect where brands with high DE still failed the f2 similarity criteria underscores that f2 is a sensitive measure of the entire dissolution curve profile, whereas DE and MDT describe the capacity and rate of the formulation[12]. This distinction is critical for concentration-dependent antibiotics like ciprofloxacin, where the initial rate of release is as vital as the total amount dissolved.

To improve the dissolution characteristics of brands with poor cumulative release, manufacturers may consider: optimizing formulation, by adjusting excipients to enhance dissolution rate; refining manufacturing processes to improve tablet structure and dissolution properties; establishing a correlation between in vitro dissolution data and in vivo performance to predict bioavailability and efficacy[13,14,17].

5. Limitation

We acknowledge that the UV spectrophotometric method used for the assay provides a total drug content estimate but may lack the specificity to distinguish between the API and potential degradation products or specific impurities. Consequently, while the f1 and f2 factors, supported by MDT and DE, indicate distinct release behaviors, these findings should be viewed as a baseline for the quality landscape of ciprofloxacin generics. Furthermore, the

absence of antimicrobial susceptibility testing limits the inferences to the physical quality and release kinetics of the tablets, rather than their direct clinical efficacy against pathogens. Finally, the observed variations may partially reflect the cumulative impact of storage conditions within the tropical supply chain of the FCT, which was not formally controlled in this

5. Conclusion

In conclusion, while all nineteen brands of ciprofloxacin 500 mg tablets met the basic pharmacopoeial requirements for drug content and disintegration, significant disparities were observed in their biopharmaceutical release profiles. Only one brand achieved statistical similarity to the comparator. However, these findings should be viewed as a preliminary quality indicator rather than a final determination of clinical failure. The results underscore the need for more stringent regulatory oversight of generic formulations in Nigeria and highlight that MDT and DE provide more granular insights into formulation efficiency than f1 and f2 alone

Reference:

1. Akinyeye RO, Adepoju AA, Orege JI, Adegbuyi AT (2021) Quality assessment of five pharmaceutical products of different brands marketed in Nigeria. *Journal of Drugs and Pharmaceutical Science,* 5: 1–12. https://doi.org/10.31248/JDPS2019.028
2. Builders PF, Egeiyeh A, Oladosu P, Kunle OO (2005) Quality assessment of some brands of Ciprofloxacin tablets on sale in Abuja. *Nigeria. Journal of Pharmacy & Bioresources*, *2*:49-54. https://doi.org/10.4314/.jpb.vi1.32061
3. FDA. Dissolution Testing of Immediate Release Solid Oral Dosage Forms. Guidance for Industry. Available online: https://www.fda.gov/downloads/drugs/guidances/ucm070237.pdf (accessed on 14 August 2025).
4. Gulumbe BH, Ridwan O (2023) Revisiting the blind spot of substandard and fake drugs as drivers of antimicrobial resistance in LMICs. *Annals of Medicine & Surgery,* 85:122-123 https://doi.org/0.1097/MS9.0000000000000113
5. Hummler H, Stillhart C, Meilicke L, Grimm M, Krause E, Mannaa M, Gollasch M, Weitschies W, Page S (2023) Impact of Tablet Size and Shape on the Swallow ability in Older Adults. *Pharmaceutics, 15*:1042-1052 https://doi.org/10.3390/pharmaceutics15041042
6. Jaman M, Chowdhury AA, Rana AA, Masum SM, Ferdous T, Rashid MA, Karim MM (2015) In vitro evaluation of Ciprofloxacin Hydrochloride. *Bangladesh Journal of Scientific and Industrial Research, 50*:251-256. https://doi.org/10.3329/bjsir.v50i4.25833
7. Jambhekar SS, Breen PJ (2013) Drug dissolution: significance of physicochemical properties and physiological conditions. *Drug Discovery Today*, 18:1173-1184. https://doi.org/10.1016/j.drudis.2013.08.013
8. Joda AE, Tayo F, Aina BA (2018) Quality assessment of ciprofloxacin tablets obtained from community pharmacies in Lagos, Nigeria. *Ife Journal of Science*, 20:155-168. https://doi.org/10.4314/ijs.v20i1.16
9. Kassaye L, Genete G (2013) Evaluation and comparison of in-vitro dissolution profiles for different brands of amoxicillin capsules. African health sciences 13:369–375. https://doi.org/10.4314/ahs.v13i2.25
10. Umesh B (2022) Successful bioequivalence investigation: current challenges and possible solutions. *Pharmaceutics,* 65: 1-12 https://doi.org/10.1002/9781119634645.ch14
11. Osadebe PO, Esimone OC, Akabogu IC (2003) An empirical assessment of the possibility of interchangeability between multisource ciprofloxacin hydrochloride tablets marketed in Nigeria. *Bollettino chimico farmaceutico*, 142: 352–356.
12. Cooper P (2024) Regulatory and scientific challenges in bioequivalence of high variable drugs. *Journal of Bioequivalence and Bioavailability*, 16:1000609 https://doi.org/10.35248/0975-0851.24.16.609
13. Ncube BM, Dube A, Ward K (2021) Establishment of the African Medicines Agency: progress, challenges and regulatory readiness. *Journal of pharmaceutical policy and practice*, 14(1): 29-39. https://doi.org/10.1186/s40545-020-00281-9
14. Ozawa S, Evans DR, Bessias S, Haynie DG, Yemeke TT, Laing SK, Herrington JE (2018) Prevalence and estimated economic burden of substandard and falsified medicines in low-and middle-income countries: a systematic review and meta-analysis. *JAMA network open*, 1(4): e181662-e181662. https://doi.org/10.1001/jamanetworkopen.2018.1662

15. Onwuliri CD, Ezebialu IU, Adebisi A (2025). Systematic review and meta-analysis of the prevalence and types of health care associated infections in Nigeria. *BMC Infectious Diseases,* 25: 836. https://doi.org/10.1186/s12879-025-11246-1

16. Nabeel M, Ali K, Sarwar MR, Waheed I (2024). Assessment of knowledge, attitudes, and practices among community pharmacists in Lahore regarding antibiotic dispensing without prescription: A cross-sectional study. *PLoS One*, 19: e0304361. https://doi.org/10.1371/journal.pone.0304361

17. Jonah JH, Samuel G, Abdullahi MI, Emmanuel EA, Danladi SS, Ekwuluo CE (2024). Nigeria's public health response to disease outbreaks: A review of strengths and weaknesses. *Journal of Public Health in Africa*, *15*(1):773. https://doi.org/10.4102/jphia.v15i1.773