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Development and validation of a UV/visible spectrophotometric method for simultaneous assay of paracetamol and ibuprofen

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ABSTRACT

Introduction
The quality of medicines and healthcare products is a significant challenge these days, with counterfeiting accounting for at least 10% of all products in circulation worldwide, including in Africa. In the specific case of the Democratic Republic of Congo (DR Congo), which is the second-largest country on the continent and faces serious challenges in frontier control, the country has become a major hub for this scourge. Counterfeit medicines circulating within its territory account for over 20% of the pharmaceutical market.

Purpose
This research aimed to provide a simple, reliable, and economical method for quality control of drugs and healthcare products in the Congolese pharmaceutical market. This was achieved by developing and validating an ultraviolet-visible (UV-vis) spectrophotometric method for the simultaneous determination of paracetamol and ibuprofen in dosage forms.

Methods
From stock solutions, 0.65 ml of paracetamol and 0.8 ml of ibuprofen were transferred into volumetric flasks to prepare 10 ml of each solution. These solutions were separately scanned between 200-400 nm to observe the absorption maxima of each compound in UV-vis spectra against the blank (ethanol). Subsequently, individual solutions were prepared to obtain calibration and validation standards for the method validation, using the total error strategy and studying various validation criteria (specificity, precision, accuracy, linearity, robustness). After evaluating all the criteria, the developed and validated method was applied for the qualitative and quantitative analysis of dosage forms containing both paracetamol and ibuprofen.

Results
When solubilized in ethanol, paracetamol and ibuprofen exhibited absorption maxima at 249 nm and 219 nm, respectively. The method demonstrated strong correlation over the concentration ranges used (2.6–9.1 µg/ml for paracetamol and 3.2–9.6 µg/ml for ibuprofen). The correlation coefficients and regression lines determined at selected wavelengths were: $y = 0.0924\ x$ ($R^2 = 0.999$) and $y = 0.0228x$ ($R^2 = 0.9996$) for paracetamol at 249 nm and 219 nm respectively, and $y = 0.0429\ x$ ($R^2 = 0.9993$) for ibuprofen at 219 nm. The committed bias and the coefficient of variation in the precision study were within ±2% and less than 2%, respectively. Furthermore, the application of the method to dosage forms produced appropriate active ingredient rates, which ranged between 98% and 102%.

Conclusion
The developed method showed no interference between the active ingredients and the usual excipients used in tablet manufacturing. The recovery rates obtained in the selectivity and accuracy studies were consistently between 98% and 102%. Active ingredient contents determined by applying the method to pharmaceutical dosage forms ranged between 95% and 105%.

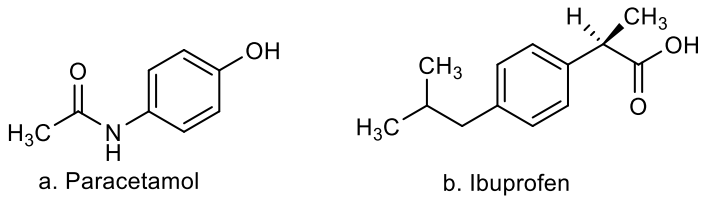
INTRODUCTION

Pharmaceutical products are popular targets for illegal trading, particularly in developing countries. These products are easy to transport, have a high value per unit, and, most critically, their quality cannot be easily assessed by laypeople or even professionals without the assistance of a quality testing laboratory. The low risk of prosecution in some countries and significant profit margins for counterfeiting drugs have enticed criminal groups, some of which are reportedly linked to the narcotics trade or other forms of organized crime (OECD/EUIPO, 2020; Al-Abdulrahman, 2023).

In the specific case of the Democratic Republic of Congo (DR Congo), which is the second-largest country on the continent and faces significant challenges with frontier control, the country has become a major hub for counterfeit pharmaceuticals. Counterfeit medicines circulating within its territory account for over 20% of the pharmaceutical market (World Health Organization [WHO], 1993; World Bank, 2005; British Pharmacopoeia Commission [BFC], 2022).

Paracetamol, scientifically known as N-(4-hydroxyphenyl) acetamide, is an analgesic-antipyretic, while ibuprofen, whose scientific name is (2RS)-2-[4-(2-methylpropyl)phenyl]propanoic acid, is an analgesic and anti-inflammatory agent. Both molecules inhibit the cyclo-oxygenase enzyme to produce their therapeutic effects (Vidal, 2018). In the Democratic Republic of Congo, these two molecules are also marketed in combination in tablet or oral suspension forms. Currently, the quantitative determination of each of these associated components is easily achieved using separative methods.

Figure 1:
Paracetamol (a) and Ibuprofen (b) structures



a. Paracetamol b. Ibuprofen

High-performance liquid chromatography (HPLC) is considered the gold standard for pharmaceutical analysis; however, it is cost-prohibitive and requires sophisticated equipment, which is often unavailable in low-resource settings. This study aims to develop a UV-visible spectrophotometric method for the simultaneous quantification of paracetamol and ibuprofen that is accessible, economical, and suitable for routine quality control in developing regions.

METHODS

Equipment

Standard paracetamol (lot: 104-200606-2, purity: 101%) and ibuprofen (lot: IBF(I) 0332042, purity: 99.8%) were purchased from Zhejiang Cuobang Pharmaceutical Co. Ltd, China, and SMS Pharmaceutical Ltd, China, respectively. Magnesium stearate, talc, corn starch, and microcrystalline cellulose were procured from India from the following suppliers: Prachin Chemical, Neelkanth Minechem, Universal Starch, and Stannmarc Enterprise.

Chemicals

In the Democratic Republic of Congo, the paracetamol-ibuprofen combination contains 325 mg and 400 mg, respectively, and is marketed under several trade names. For this study, the following commercially available products were analyzed: Coreflam (lots: 2FLM02 and 3FLM03), Anaflam (lots: T31124, T3667, T4079, T3844, T31125, T3830, T3832, and T3863), Uflam (lots: AGI23001A and AGI22002A), and Cesafam (lot: AHN001). Absolute ethanol (99.9% v/v) used as the solvent was obtained from VWR Chemicals, France.

Method

Preparation of Paracetamol and Ibuprofen Standard Stock Solutions

Ten milligrams of each substance were accurately weighed and separately transferred into 100 ml volumetric flasks containing 50 ml ethanol. After stirring for 5 minutes in an ultrasonic bath, the volumes were adjusted to the mark with ethanol to achieve 100 µg/ml solutions.

Wavelength Selection

From the respective stock solutions, 0.65 ml of paracetamol and 0.8 ml of ibuprofen were transferred into separate 10 ml volumetric flasks, and the volumes were adjusted with ethanol. The solutions were scanned spectrophotometrically between 200–400 nm against ethanol as a blank.

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Method Validation

The method was validated according to the International Conference on Harmonization (ICH) guidelines, assessing linearity, precision, accuracy, selectivity/specificity, robustness, limits of detection (LOD), and limits of quantification (LOQ) (ICH, 1996, 2005; US Federal Government, 2001).

Preparation of Calibration Standard Solutions for Paracetamol and Ibuprofen

From the stock solutions, specific volumes were diluted with ethanol in 10 ml volumetric flasks to obtain the desired concentrations: 0.26, 0.39, 0.52, 0.65, 0.78, and 0.91 ml for paracetamol, and 0.32, 0.48, 0.64, 0.8, and 0.96 ml for ibuprofen. Calibration curves were constructed by plotting absorbance versus concentration, and correlation coefficients were calculated **(Figures 3 and 4)** (OECD/EUIPO, 2020; Skoog et al., 2003).

Using linearity data, specific absorbances were calculated at the maximum absorption wavelengths using the formula:

$$A_{1Cm}^{1\%} = \frac{Absorbance}{Concentration}$$

A system of two equations with two unknowns was established based on Beer-Lambert's law of additivity (Skoog et al., 2003; Skoog et al., 2015; Gummadi et al., 2012).

Preparation of Solutions for the Fidelity Study

Solutions containing 5.2, 6.5, and 7.8 µg/ml for paracetamol and 4.8, 8, and 9.6 µg/ml for ibuprofen were prepared from standard stock solutions. These were analyzed to determine intra-day (repeatability) and inter-day (intermediate precision) precision over three consecutive days.

Limits of Detection (LOD) and Quantification (LOQ)

Using linearity data by applying the least-squares method, the slopes of the regression lines and the standard deviations on the y-intercept for each of the substances were finally calculated to determine the limits of detection (LOD) and quantification (LOQ) using the following formulas:

$$LOD = \frac{S_b \times 3}{S}$$

$$LOQ = \frac{S_b \times 10}{S}$$

where S_b is the standard deviation of the y-intercept, and S is the slope of the regression line (Gummadi et al., 2012; Dey et al., 2012).

Preparation of Mixed Solution of Paracetamol and Ibuprofen Standards

A mixture of 65 mg paracetamol and 80 mg ibuprofen was dissolved in 50 ml ethanol using an ultrasonic bath and diluted to 100 ml to obtain a solution containing 650 µg/ml paracetamol and 800 µg/ml ibuprofen.

Determination of Method Accuracy

The accuracy of the method was calculated by applying the standard addition method at three concentration levels (80%, 100% and 120%), followed by determination of the recovery rates at each level: 20 cesaflam tablets (Lot: AHN001) were weighed one by one, then finely ground using a mortar and pestle, then a quantity of this powder equivalent to 10 mg ibuprofen calculated from the average weight of 20 tablets was accurately weighed and transferred to a 100 ml volumetric flask containing 50 ml ethanol. The mixture was stirred in an ultrasonic bath for 15 minutes at 55°C, then the volume was made up to the mark with the same solvent. After mixing and filtration through Wattman filter paper (No. 41) ; 0.8 ml of pre-analyzed filtrate was transferred to three different 100 ml volumetric flasks in which ibuprofen and paracetamol concentrations were fortified with 0.8; 1 and 1.2 ml of the standard mixing solution, respectively, and the volumes were made up to the mark with ethanol to obtain pre-analyzed cesaflam solutions spiked with 80% ; 100% and 120% paracetamol and ibuprofen, respectively.

Absorbances were measured and recoveries calculated according to the following formula:

$$\% = \frac{\boldsymbol{C_f - C}}{\boldsymbol{C_a \times 100}}$$

where C_f is the concentration of the fortified sample, C is the unfortified concentration, and C_a is the added concentration (ICH, 1996; Mendham et al., 2015; Aboud et al., 2017; Jain et al., 2011).

Placebo Solution

A mixture of corn starch, magnesium stearate, talc, and

microcrystalline cellulose (5 mg each) was dissolved in 30 ml ethanol, stirred for 15 minutes at 55°C in an ultrasonic bath, and diluted to 50 ml. The resulting mixture was filtered through Wattman filter paper (No. 41). The resulting solution contained 100 µg/ml of each component.

Specificity/Selectivity

In a series of three 10 ml volumetric flasks, each containing 0.1 ml of the paracetamol and ibuprofen standard mixing solution, 0.8 ml, 1 ml, and 1.2 ml of the placebo mixture were added, respectively, to give 8, 10 and 12 µg/ml, i.e. 80, 100 and 120% of each placebo component.

Recovery rates for placebo mixtures were calculated as:

$$\% = \frac{Q_P}{Q_M} \times 100$$

where % = recovery rate, Q_P is the quantity in the placebo mixture, and Q_M is the quantity in the standard solution (Ermer et al., 2005; Snyder et al., 1997).

Method Robustness

Robustness was evaluated by analyzing a sample of compressed Anaflam (batch: T3830) using two analysts on the same equipment and day.

Application to Pharmaceutical Forms

Twenty tablets from each drug lot were weighed individually, ground to a fine powder, and analyzed as described. Absorbance values and specific absorbances at key wavelengths were used to calculate drug concentrations (Skoog et al., 2003):

$$A_{249} = 933\ C_{p1}$$
$$A_{219} = 228\ C_{p2} + 432 C_{i2}$$

Where,

A_{249} is the absorbance of the sample at 249 nm

A_{219} is the absorbance of the sample at 219 nm

933 and 228 are the specific absorbances of paracetamol at 249 nm and 219 nm respectively.

C_{p1} and C_{p2}, are paracetamol concentrations at 249 nm and 219 nm respectively;

432, is the specific absorbance of ibuprofen at 219 nm;

C_{i2} is the concentration of ibuprofen at 219 nm.

Statistical Analysis and Software

Results are presented as mean ± standard deviation. Statistical analysis and graphs were generated using ENOVA Excel (free version).

RESULTS

Linearity

Using ethanol as the solvent, paracetamol exhibited an absorption maximum at 249 nm, while ibuprofen, which did not absorb at this wavelength, showed its absorption maximum at 219 nm. Both wavelengths were retained for further experimentation **(Figures 1 and 2)**.

Figure 1:
Paracetamol spectrum at 249 nm

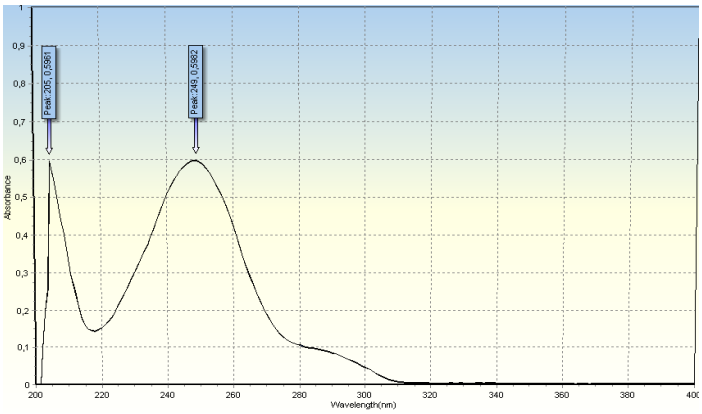
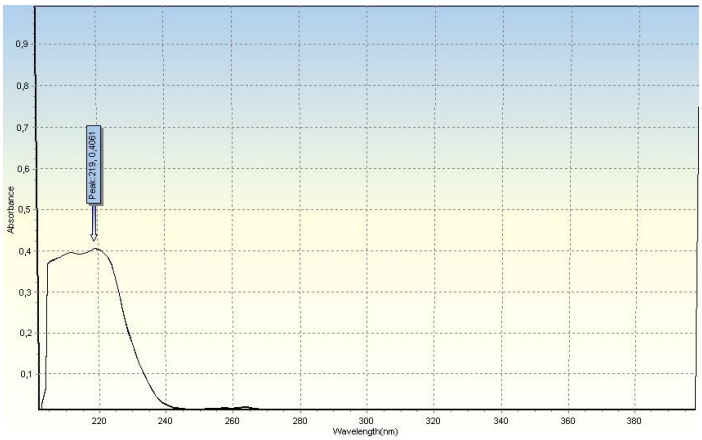


Figure 2:
Ibuprofen spectrum at 219 nm



The method demonstrated excellent linear correlation between the introduced concentrations and their respective measured absorbances. The regression lines at the selected wavelengths were y = 0.0924 x (R^2 = 0.999) and y = 0.0228x (R^2 = 0.9996) for paracetamol at 249 nm and 219

nm respectively, and y = 0.0407 x (R^2 = 0.9993) for ibuprofen at 219 nm. All correlation coefficient values are greater than or equal to 0.999 ($R^2 \geq 0.999$) (12 and13) **(Figures 3, 4, and 5)**.

Figure 3:
Paracetamol regression at 249 nm

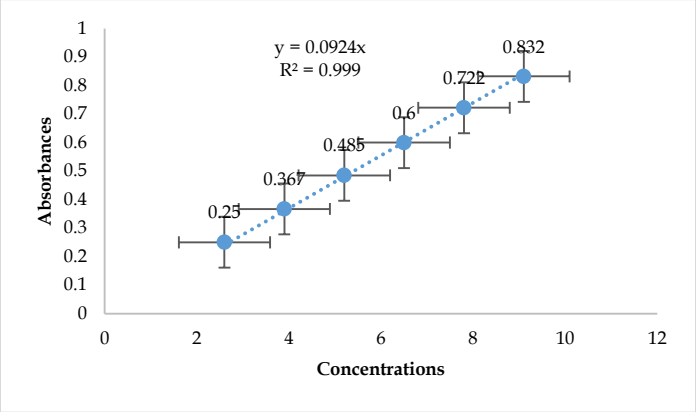


Figure 4:
Paracetamol regression at 219 nm

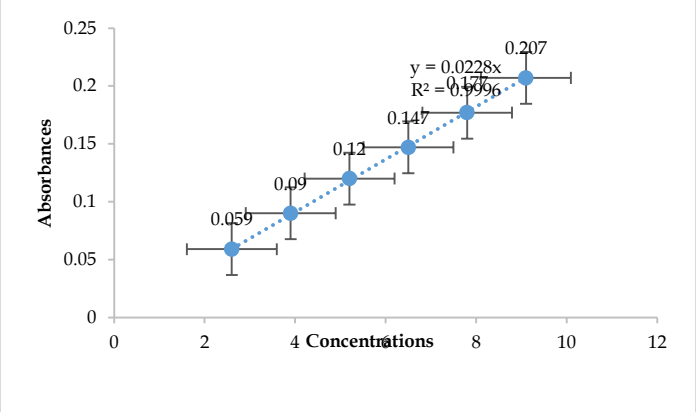
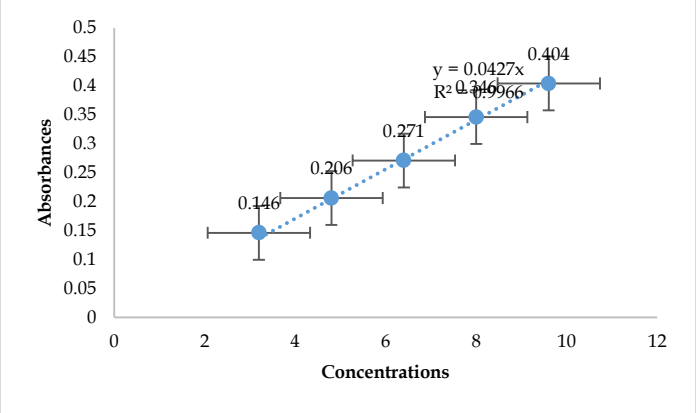


Figure 5:
Ibuprofen regression at 219 nm



The introduced concentrations, measured absorbances of calibration standard solutions, and linearity study parameters are shown in **Tables 1 and 2**.

Table 1:
Calibration standards for paracetamol and ibuprofen (n=6)

Paracetamol			*Ibuprofen*	
Concentrations (µg/ml)	**Absorbances**		**Concentrations (µg/ml)**	**Absorbances**
	219 nm	249 nm		219 nm
2,6	0,059	0,250	3,2	0,146
3,9	0,090	0,367	4,8	0,206
5,2	0,120	0,485	6,4	0,271
6,5	0,147	0,600	8	0,346
7,8	0,177	0,722	9,6	0,410
9,1	0,207	0,852	-	-

Based on the linearity study data, specific absorbances, detection, and quantification limits were calculated for both substances. A system of two equations with two unknowns was also established. The results are presented in **Tables 2–5**.

Table 2:
Specific absorbances of paracetamol at 249 nm (n=6)

N°	Concentrations (µg/ml)	Absorbances	Absorbances spécifiques $A_{1cm}^{1\%}$
1	2,6	0,251	965,384
2	3,9	0,369	946,153
3	5,2	0,490	942,307
4	6,5	0,600	923,076
5	7,8	0,714	915,384
6	9,1	0,826	907,692
Specific absorbances mean			**933,332**

Table 3:
Specific absorbance of Paracetamol in various concentrations at 219 nm (n=6)

N°	Concentrations (µg/ml)	Absorbances	Absorbances spécifiques
1	2,6	-	-
2	3,9	-	-
3	5,2	0,120	230,7692308
4	6,5	0,147	226,1538462
5	7,8	0,178	228,2051282
6	9,1	0,207	227,4725275
Specific absorbances mean			**228,1501832**

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Table 4:
Specific absorbances of Ibuprofen in various concentrations at 249 nm

N°	Concentrations (µg/ml)	Absorbances	Absorbances spécifiques $A_{1Cm}^{1\%}$
1	3,2	0,146	456,25
2	4,8	0,206	429,1666667
3	6,4	0,271	423,4375
4	8	0,346	432,5
5	9,6	0,410	427,0833
Specific absorbances mean			**433,68749334**

Tables 5:
Paracetamol and Ibuprofen linearity parameters

Validation parameters	**Paracetamol**		**Ibuprofen**
λmax	249 nm	219 nm	219 nm
Concentrations	2,6 - 9,1 µg/ml	2,6 -9,1 µg/ml	3,2- 9,6 µg/ml
Regression	Y = 0,0924x	Y = 0,0228x	Y = 0,0429x
Correlation coefficients (R^2)	**0,999**	**0,9996**	**0,9993**
LOD	0,6006 µg/ml	0,4534 µg/ml	0,1439 µg/ml
LOQ	2,002 µg/ml	1,5113 µg/ml	0,4798 µg/ml
Specific absorbances	933,332	228,150	433,6
Equation systems	$A_{249} = 933\ C_{p1}$ $A_{219} = 228\ C_{p2} + 433{,}6\ C_{i2}$		

where

A_{249} is the absorbance of the sample at 249 nm;

A_{219} is the absorbance of the sample at 219 nm;

933 is the specific absorbance of paracetamol at 249 nm;

C_{p1} and C_{p2} are paracetamol concentrations at 249 nm and 219 nm respectively;

228 and 433.6 are specific absorbances of paracetamol and ibuprofen respectively at 219 nm;

C_{i2} is the ibuprofen concentration at 219 nm.

Repeatability and intermediate precision

The method showed good intra-day precision and intermediate precision for both substances, with bias within −2% to +2%. Coefficients of variation (CV) were below 2%. Results are detailed in **Tables 6 and 7**.

Table 6
Precision for paracetamol at 249 nm and 219 nm (n=6)

	Paracetamol at 249 nm			**Paracetamol at 219 nm**		
Introduced Concentrations (µg/ml)	5,2	6,5	7,8	5,2	6,5	7,8
Variation intra-day (µg/ml)	5,28	6,51	7,84	5,30	6,44	7,80
% Recovery	101,53	100,15	100,15	101,92	99,07	100,00
% Bias	**1,53**	**0,15**	**0,51**	**1,92**	**- 0,92**	**0,00**
% CV	**0,27< 2**	**0,86< 2**	**0,54< 2**	**0,82< 2**	**1,08< 2**	**0,04< 2**
Variation inter-day (µg/ml)	5,27	6,45	7,78	5,26	6,44	7,80
% Recovery	101,35	99,23	99,74	101,15	99,07	100
% Bias	1,34	0,76	-0,25	1,15	-0,92	0,00
% CV	1,33< 2	0,69< 2	0,55 < 2	0,39	0,32	1,47

Table 7:
Method precision regarding Ibuprofen at 219 nm (n=6)

	Ibuprofen		
Introduced Concentrations (µg/ml)	4,8	8	9,6
Variation intra-day (µg/ml)	4,79	8,00	9,70
% Recovery	99,79	100,00	101,04
% Bias	**-0,20**	**0,00**	**1,04**
% CV	**0,62 < 2**	**0,69 < 2**	**0,80 < 2**
Variation inter-day (µg/ml)	4,84	8,00	9,68
% Recovery	100,83	100,00	100,83
% Bias	**0,83**	**0,00**	**0,83**
% CV	**1,34 < 3**	**0,59 < 3**	**0,11< 3**

Method Accuracy

The developed method demonstrated good accuracy, with recovery rates ranging from 98% to 102%. **Tables 8 and 9** summarise these findings.

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Table 8:
Accuracy for paracetamol method

N°	Cesaflam Tablets analysé (µg/ml)	% Standard added	Standard recovered (µg/ml)	% Recovery	Means
	6,4094	80	5,0161	99,66	
	6,4094	80	5,0268	99,87	
	6,4094	80	5,0589	100,51	
1	6,4094	80	5,0804	100,93	100,89
	6,4094	80	5,1447	102,21	
	6,4094	80	5,1447	102,21	
	6,4094	100	6,3237	100,51	
	6,4094	100	6,3987	101,70	
	6,4094	100	6,4416	102,38	
2	6,4094	100	6,4094	101,87	101,44
	6,4094	100		100,51	
	6,4094	100	6,3237	101,70	
			6,3987		
	6,4094	120	7,7063	102,07	
	6,4094	120	7,5777	100,36	
	6,4094	120	7,6849	101,78	
3	6,4094	120	7,5670	100,22	101,07
	6,4094	120	7,6206	100,93	
	6,4094	120	7,6313	101,07	

Table 9:
Accuracy for ibuprofen method

N°	Cesaflam tablet analysé (µg/ml)	% Standard added	Standard recovered (µg/ml)	% Recovery	Means
	8,2120	80	6,1148	97,98	
	8,2120	80	6,1559	98,64	
	8,2120	80	6,1865	99,13	
1	8,2120	80	6,1760	99,42	98,81
	8,2120	80	6,1909	99,20	
	8,2120	80	6,1215	98,54	
	8,2120	100	7,6058	97,75	
	8,2120	100	7,5692	97,02	
	8,2120	100		97,94	
2	8,2120	100	7,6408	99,63	98,21
	8,2120	100	7,7723	98,68	
	8,2120	100		98,21	
			7,6984		
			7,6617		
	8,2120	120	9,4073	100,49	
	8,2120	120	9,2618	98,94	
	8,2120	120	9,2558	98,87	98,86
3	8,2120	120	9,2902	99,24	
	8,2120	120	9,0788	96,98	
	8,2120	120	9,2356	98,66	

Specificity/selectivity of the method of the method

The method developed proved selective, giving recovery rates of between 98 and 102% in all cases **(Tables 10 and 11)**.

Table 10:
Paracetamol Specificity/Selectivity

N°	Introduced Standard (µg/ml)	Introduced Standard (%)	Introduced Concentrations means (%)	%Placebo added	Standard recovered (µg/ml)	% Recovery	Means(%)
	6,4630	99,43		80	6,4687	99,52	
	6,3879	98,27		80	6,4302	98,93	
	6,4530	99,27		80	6,4405	99,08	
1	6,4201	98,77	99,01	80	6,4537	99,28	99,29
	6,4308	98,93		80	6,3772	99,16	
	6,4630	99,43		80	6,4830	99,74	
	6,4630	99,43		100	6,4572	99,34	
	6,3879	98,27		100	6,4001	98,46	
	6,4530	99,27		100		99,10	
2	6,4201	98,77	99,02	100	6,4415	98,95	99,00
	6,4308	98,93		100		98,89	
	6,4630	99,43		100	6,4323	99,26	
					6,4301		
					6,4523		
	6,4630	99,43		120	6,4737	99,59	
	6,3879	98,27		120	6,4415	99,10	
	6,4530	99,27		120	6,3665	98,65	
3	6,4201	98,77	99,01	120	6,4951	99,92	99,30
	6,4308	98,93		120	6,4308	98,93	
	6,4630	99,43		120	6,4415	99,66	

Table 11:
Ibuprofen Specificity/Selectivity

N°	Introduced Standard (µg/ml)	Introduced Concentrations means (%)	Introduced Standard (%)	%Placebo added	Standard recovered (µg/ml)	% Recovery	Meanss (%)
	8,1553	101,94		80	8,1256	101,57	
	8,0836	101,04		80	8,1457	101,82	
	8,1216	101,52		80	8,1388	101,73	
1	8,1373	101,71	101,52	80	8,1121	101,40	101,60
	8,1015	101,26		80	8,1277	101,59	
	8,1321	101,65		80	8,1201	101,50	
	8,1233	101,54		100	8,1040	101,30	
	8,0836	101,04		100	8,0836	101,04	
	8,1216	101,52		100		101,40	
2	8,1273	101,59	101,41	100	8,1120	101,71	101,29
	8,1015	101,26		100		100,91	
	8,1221	101,52		100	8,1374	101,42	
					8,0731		
					8,1142		
	8,1330	101,66		120	8,1258	101,57	
	8,0836	101,04		120	8,0520	100,65	
	8,1216	101,52		120	8,0856	101,07	
3	8,1173	101,46	101,22	120	8,1479	101,84	101,41
	8,1015	101,26		120	8,1404	101,75	
	8,0321	100,40		120	8,1278	101,59	

Table 12:
Selectivity comparason between paracetamol and Ibuprofen

	Paracetamol			Ibuprofen		
	80%	100%	120%	80%	100%	120%
Calculated t-Student	2,296	0,155	1,451	1,284	1,023	1,014
First-class error (**α**)	0,05	0,05	0,05	0,05	0,05	0,05
Degree of freedom (**ν**)	5	5	5	5	5	5
Theorical t-Student test (**0,05 ; 5**)	2,571					

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Method robustness

The results obtained by two analysts on the same sample using the validated method are not significantly different, which justifies the robustness of the method (Table 13).

Table 13:
Method robustness

	Analyst 1		*Analyst 2*	
N°	**% Paractamol**	**% Ibuprofen**	**% Paracetamol**	**% Ibuprofen**
1	101,74	99,41	100,90	98,31
2	101,07	97,66	100,90	97,74
3	100,90	97,45	99,75	95,91
4	100,58	97,87	99,60	95,99
5	101.74	99,69	100,75	97,23
6	102,72	100,71	100,90	97,74
Means ± %RSD	**101,45 ± 0,62**	**98,80 ± 1,22**	**100,47 ± 0,55**	**97,15 ± 0,93**

Application of the method to finished products

The method developed was immediately applied to pharmaceutical dosage forms. The results are shown in Table 14.

Table 14:
Simultaneous quantification of paracetamol and Ibuprofen in dosage forms results

	Absorbances		*Absorbances means*		*% ± CV*	
Batches n°	**249 nm**	**219 nm**	**249 nm**	**219 nm**	**Paracetamol**	**Ibuprofen**
2FLM02	0,622	0,501				
	0,624	0,501	0,623	0,500	102,78 ± 0,15	100,79 ± 0,17
	0,624	0,500				
3FLM03	0,587	0,486				
	0,588	0,487	0,587	0,486	96,84 ± 0,07	99,29 ± 0,24
	0,587	0,486				
T31124	0,615	0,500				
	0,623	0,500	0,620	0,500	102,34 ± 0,65	100,78 ± 0,28
	0,624	0,500				
T3667	0,627	0,503				
	0,626	0,503	0,626	0,503	103,22 ± 0,13	101,28 ±0,05
	0,625	0,503				
T4079	0,600	0,485				
	0,598	0,485	0,598	0,485	98,71 ± 0,16	98,00 ± 0,07
	0,598	0,485				
T3844	0,625	0,488				
	0,625	0,492	0,625	0,490	103,35 ± 0,21	97,63 ± 0,48
	0,627	0,491				
T31125	0,610	0,500				
	0,610	0,500	0,610	0,500	100,58 ± 0,00	101,54 ± 0,00
	0,610	0,500				
T3830	0,619	0,500				
	0,619	0,500	0,619	0,499	102,07 ± 0,00	100,80 ± 0,13
	0,619	0,499				
T3832	0,582	0,480				
	0,581	0,480	0,580	0,480	95,75 ± 0,21	97,82 ± 0,09
	0,579	0,480				

DISCUSSION

The method developed showed good linearity and an excellent correlation between the ranges of concentrations introduced and the absorbances measured, with the correlation coefficient values obtained in all cases being less than 0.999. No interference was observed with the matrix used, as the paracetamol and ibuprofen contents obtained before and after the placebo were not significantly different. Furthermore, the matrix used as the blank for control did not absorb UV-Vis light at the selected wavelengths of paracetamol and ibuprofen, indicating that there should not be any absorption from it due to absorbance additivity, which could bias the overall

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results. The recovery rate in the accuracy study ranged from 98.0% to 102.0%. When applied to drug samples, the method enabled the determination of active ingredient contents in the 95% to 105% range. These results align with both the US Pharmacopeia standard (90% to 110%) (USP 44-NF39, 2021) and the UK Pharmacopeia standard (95% to 105%) (BP, 2023) for both molecules.

The proposed method's simplicity and cost-effectiveness make it a valuable alternative to HPLC for routine analysis in laboratories with limited resources. However, the scalability of the method should be assessed further, particularly in industrial contexts where high throughput is required.

CONCLUSION

The method developed is simple, rapid, reliable, selective, specific, and cost-effective. It can, therefore, be used as an alternative to separative techniques for the routine testing and quantification of paracetamol and ibuprofen in combination, for quality control of pharmaceutical dosages circulating in developing countries such as the DR Congo, particularly those containing both paracetamol and ibuprofen. This method does not require expensive equipment or reagents. All validation criteria met the required standards, allowing it to be applied for the direct determination of active ingredients, with a recovery rate ranging between 98% and 102% in the tested dosage forms.

Ethics Approval: Not applicable.

Conflicts of Interest: None declared.

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