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Flow Injection Spectrophotometric Indirect Assay of Amlodipine Besylate Using Crystal Violet Agent

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Abstract

Amlodipine Besylate (AMB) was determined in pharmaceutical and biological samples using a continuous-flow injection technique characterized by simplicity, rapidity, cost-effectiveness, sensitivity, and a broad linear range. This study aims to develop and evaluate a flow injection analysis method for the rapid and reliable determination of Amlodipine in chemical and biological samples using minute quantities. The suggested method is based on the oxidation of the drug with a potassium bromide-potassium bromate mixture, followed by reaction with crystal violet as a reagent to produce a blue product, the absorbance of which was measured at 592 nm. The coefficient of determination (R2) is 0.9978, and the calibration curve's linear range is 10-250 µg/mL. The limit of detection for the standard was 2.46 µg/mL, the recovery was 99.81%, and the relative standard deviation was 2.4%. The proposed method was successfully used to estimate AMB in biological and pharmaceutical samples. Compared with those obtained using a United States Pharmacopeia reference method, the results were favorable, and at the 95% confidence level, there was no discernible difference in accuracy and precision.

Keywords: Amlodipine Besylate, Crystal violet, Flow injection, Merging zone.

1. Introduction

Amlodipine besylate (AMB), chemically name is 3-ethyl 5-methyl (4RS)-2-[(2 aminoethoxy)methyl]-4-(2-chlorophenyl)-6-methyl-1,4-dihydropyridine- 3,5 dicarboxylate benzene sulphonate[1]. AMB is an antihypertensive calcium channel blocker medication, This drug, part of the dihydropyridine class, is a calcium channel blocker that stimulates the arterial wall muscular relaxation and lowers blood pressure[2]. The link between stroke and myocardial infarction has not been proven yet. It can also be used for dilated cardiomyopathy and shows improvements in plasma and myocardial catecholamines while significantly decreasing calcium deposition[3]. Research has shown that Amlodipine can induce apoptosis and inhibit cell proliferation[4]. Amlodipine is useful for treating unstable (Prinzmetal's) angina because it causes vasodilation of the coronary arteries, increasing oxygen delivery to the heart[5]. Several analytical methods, including high-performance liquid chromatography (HPLC), were used to estimate AMB[6-10]. Mass spectrometry (MS) and gas chromatography (GC) together[11], liquid chromatography[12], fluorimetry[13], thin layer chromatography (TLC)[14,15], spectrophotometry[16-19], hydrophilic interaction thin layer chromatography (HITLC)[20]. Flow injection analysis (FIA) is a simple, flexible, rapid technique for chemical analysis. It is considered one of the methods used to automate other methods and depends on the chemical and physical properties of the specimen region; it is also distinguished by its ability to analyze a large number of samples, its high sensitivity to chemical tests, and its high effectiveness[21]. FIA involves injecting the sample into a carrier stream, often water. The injected sample creates a zone that moves toward the reagent,

resulting in continuous detection of the target analyte[22]. This study aims to develop and evaluate an FIA method for the rapid and reliable determination of Amlodipine in chemical and biological samples using minute quantities. It also exhibits excellent compatibility with both automated and semi-automated analytical processes.

2. Materials and Methods

2.1. Devices

UV-VIS spectrophotometer (Shimadzu 1800, Japan), four-channel INNOFLUID LabN1 pump (Biobase China), and sensitive balance (Sartorius BL210S, Germany). The FI system consists of a Kompensograph C1032 recorder (Sartorius, Germany), Teflon tube 0.5 mm ID, and injection valve.

2.2. Materials

All chemicals used in this study were of analytical reagent grade and were used without further purification. AMB 99% from SDI Samarra Iraq, CV 99 % sigma Aldrich. KBr-$KBrO_3$ 98 % from Merck. Hydrochloric acid (HCL 36%) from Merck. Interferences, such as glucose, lactose, sucrose, cellulose, and sodium citrate (99%), were obtained from SDI, Samarra, Iraq. Ethanol and distilled water (DW) were used as solvents.

2.3. Methods

• AMB 1000 µg/mL solution was prepared by dissolving 0.1 g of AMB in 10 mL of ethanol in a 100 mL volumetric flask, then filling to the mark with ethanol.

• KBr-KBrO3 solution: The mixture was made by dissolving 0.1 g of potassium bromate and 1 g of potassium bromide in 100 mL of WD, then 2.5 mL was added, which was then diluted with DW in a 100 mL volumetric flask.

• CV (2.4×10^{-4} M): The CV solution was prepared by dissolving 0.01 g of CV in 10 mL of DW, then transferring the solution to a 100 mL volumetric flask and to the mark with DW.

• HCL (1M): To prepare a 1M HCL solution, 8.6 mL of concentrated HCL was diluted with DW in a 100 mL volumetric flask.

• Chemical samples preparation. To prepare the formulation's stock solution, precisely weigh 10 tablets, each containing 10 mg of pure medication. After the pills were ground into a powder, 100 mg of AMB powder was added to a 100 mL conical flask. After the addition of 25 mL of ethanol, the mixture was sonicated for 10 minutes. After passing the mixture through the Whitman filter paper, it was transferred to a 100 mL volumetric flask. For each of the four drug formulations, a stock solution containing 1000 µg/mL of AMB was prepared by adding ethanol as the solvent to the flask until the desired volume was reached.

• Biological samples preparation: The FIA approach was successfully used to estimate AMB in biological materials serum and plasma. A standard volumetric flask 10 mL was filled with 1 mL of each biological sample to create a series of spiked solutions. Followed by the addition of 1 mL of 1000 µg/mL of AMB solution.

• Preparation of interferences: Using a 100 mL standard volumetric flask, (0.1) g of any one of the following interferences: Glucose, lactose, sucrose, cellulose, and sodium citrate was dissolved.

3. Results

3.1. Spectrophotometric method

3.1.1. Estimation of wavelength

To determine the optimal wavelength, 1 mL of the oxidizing agent mixture was added to a 10 mL volumetric flask containing 1 mL of a standard solution of AMB at 1000 µg/mL (100 µg/mL) in an acidic medium (0.5 mL of 1 M HCl). Then, 1 mL of 2.4×10^{-4} M CV reagent solution was added, and the volume was brought to the mark with DW.

The absorbance was measured with a spectrophotometer, and the optimal wavelength was 592 nm, as shown in **Figure 1**.

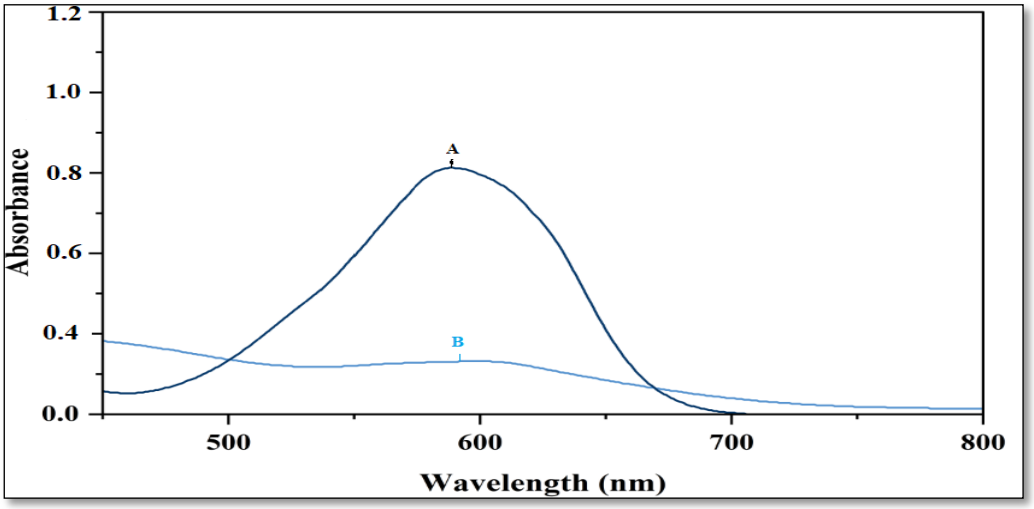
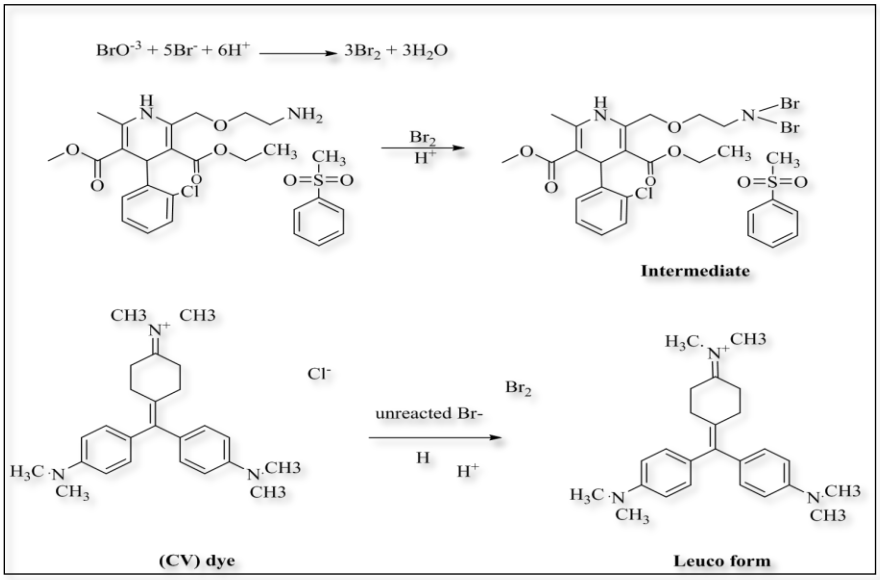


Figure 1. UV–Vis spectra of the AMB product (curve A) and the blank (curve B) measured against ethanol

3.1.2. Proposed mechanism

The proposed mechanism for AMB included oxidation of AMB by a mixture of potassium bromide and bromate as an oxidizing agent, and reduction of the product by CV dye in an acidic medium to produce a blue-colored product, forming the basis of the suggested reaction[23], as shown in **Scheme 1**.



Scheme 1. The reaction of AMB with the reagent

3.1.3. Preliminary investigation

To determine the optimal conditions for the chemical variable, initial research was conducted to identify the optimal volume or concentrations of CV, KBr/$KBrO_3$, and HCl. The optimum effect of KBr-$KBrO_3$ was estimated using different concentrations of 6.87-41.25 of 275 µg/mL, and it was found that a 27.5 µg/mL (1 mL) solution gave the highest absorbance value. Optimal concentration of the reagent CV was examined by using different concentrations 0.6×10^{-5} – 4.8×10^{-5} M of 2.4×10^{-4} M, the concentration 3×10^{-5} M (1.25 mL) provided the best absorbance result with 100 µg/mL AMB. To determine the optimal concentration or volume, HCl solutions at 0.25 –1.5×10^{-1} M were used. The highest concentration observed was 0.5×10^{-1} M (0.5 mL). Therefore, to determine the optimal addition sequence that produced the highest absorbance, the

effect of the addition sequence on absorbance was examined. The outcome was (chemical products + oxidizing + acid + reagent), as seen in **Figures 2a, 2b, 2c,** and **2d**.

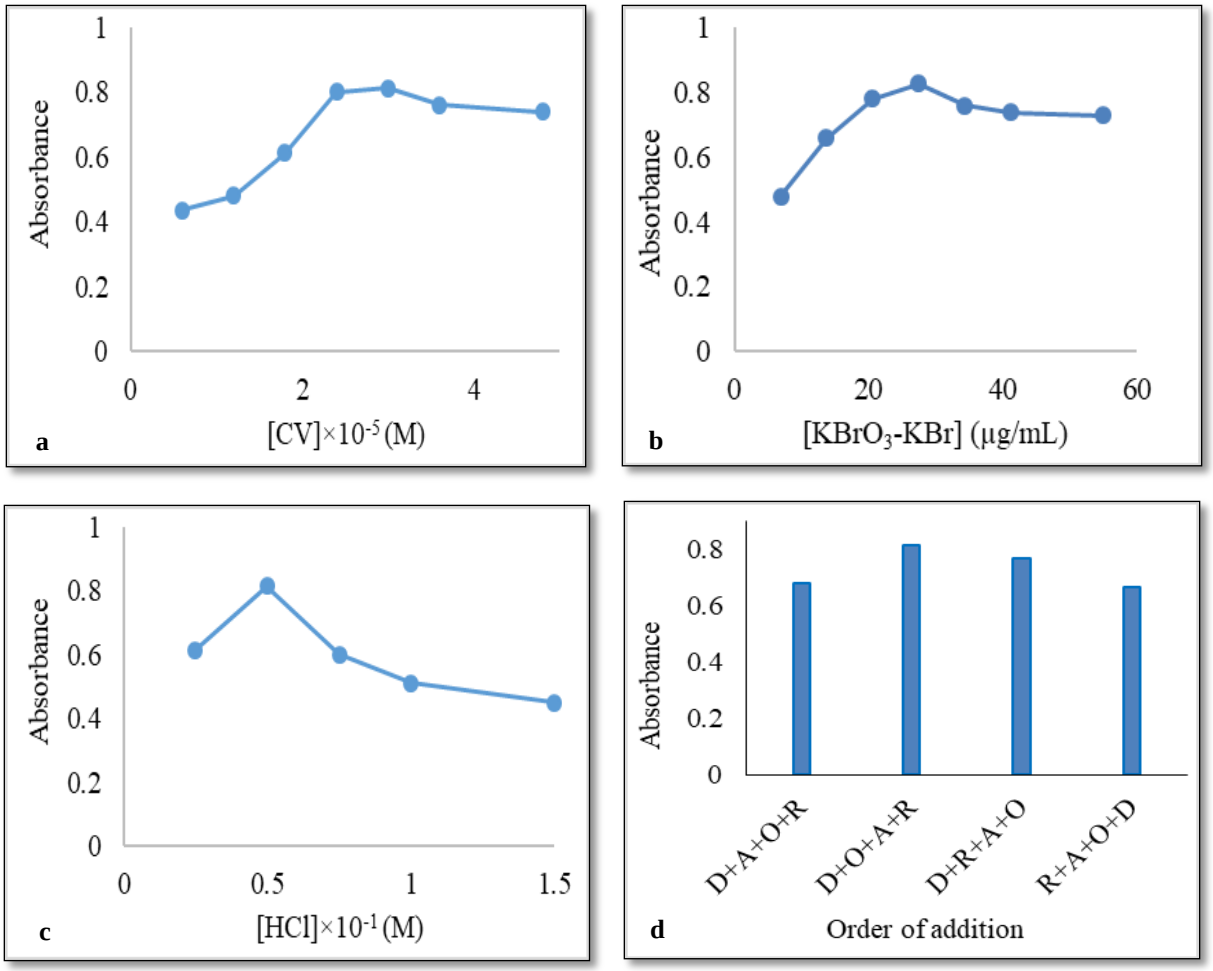


Figure 2. A-Impact of CV, B-Impact of (KBr-$KBrO_3$), C-Impact of HCL, D-Impact of order of addition

3.1.4. Calibration graph

A series of standard AMB solutions was prepared in a 10 mL volumetric flask. Chemical variables, including the oxidizing agent, acid, and reagent, were then added. The absorbance was measured at 592 nm using a UV-Vis spectrophotometer, and a linear range was observed from 5 to 90 µg/mL. As shown in **Figure 3**. **Table 1** illustrates that the traditional approach provides high accuracy and precision.

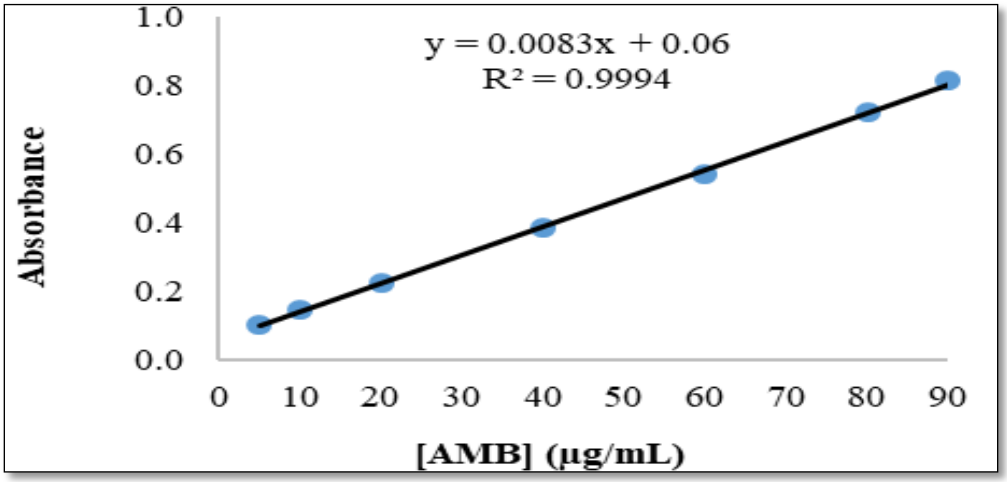


Figure 3. Calibration graph of (AMB)

Table 1. Accuracy and precision for spectrophotometric method

AMB µg/mL		Rec	E%	RSD
Present	**Found**			
20	19.49	97.44	-2.559	3.476
60	59.36	98.94	-1.059	1.137

* Average of five determination

3.1.5. The mole ratio and job's methods

A concentration of 2.2×10^{-4} M for each drug and reagent was prepared to determine the interaction rate between the AMB and CV. The results showed that the reaction rate was 1:1, as shown in **Figures 4A** and **4 B**.

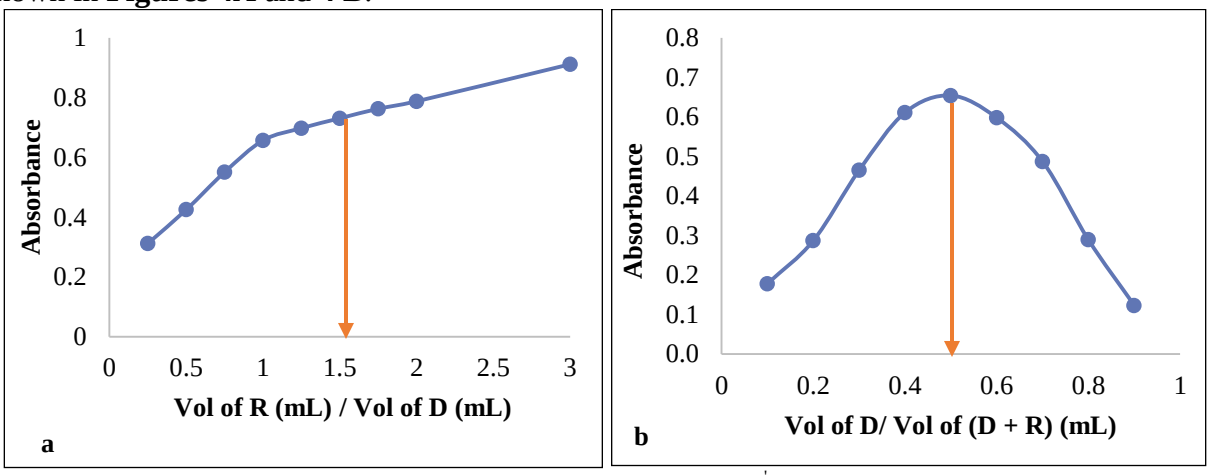


Figure 4. A-Mole-ratio method of (AMB) B- Job's method of (AMB)

3.1.6. Stability constant

The stability constant for the reaction of AMB with CV was calculated based on the stoichiometric ratio (1:1) of the drug to the reagent and according to the equation:

$$D + R \rightleftharpoons DR$$

$$\alpha C \quad \alpha C \quad (1-\alpha)C$$

$$K = \frac{[DR]}{[D][R]} \qquad K = \frac{(1-\alpha)}{\alpha^2 C}$$

K: The stability constant. α: the degree of dissociation, C: The molar concentration, Am: absorbance readings after adding enough of the reagent, As: A stoichiometric quantity of the reagent combined with absorbance in the aqueous solution. **Table 2** and the following equation were used to determine the spontaneous complex building reaction (ΔG value) according to K evaluation: $\Delta G = -RT \ln K$

Table 2. Stability constant of ADB-CV reaction

No.	Am	As	Degree of dissociation (α)	K ($L^1.mol^{-1}$)	ΔG ($J.mol^{-1}$)
1	0.698	0.657	0.05874	12400249	-40487
2	0.700	0.659	0.05857	12473636	-40502
Average				12436942	-40494

3.2. FIA/MZ spectrophotometric determination

A batch spectrophotometric method was developed using FIA/MZ after the optimal conditions for the AMB reaction with CV were determined by conventional spectrophotometry. This enabled the analysis of the most practical parameters and the development of a rapid spectral automation method for estimating AMB. As a result, the FIA technique was developed based on the batch technique.

3.2.1. The system's flow injection manifold

The continuous FIA merging zone (CFIA/MZ) design, used for AMB determination as shown in **Figure 5**, consists of a transporter current, an injection valve, Teflon loops containing the chemical used for AMB estimation, a peristaltic pump, and a recorder.

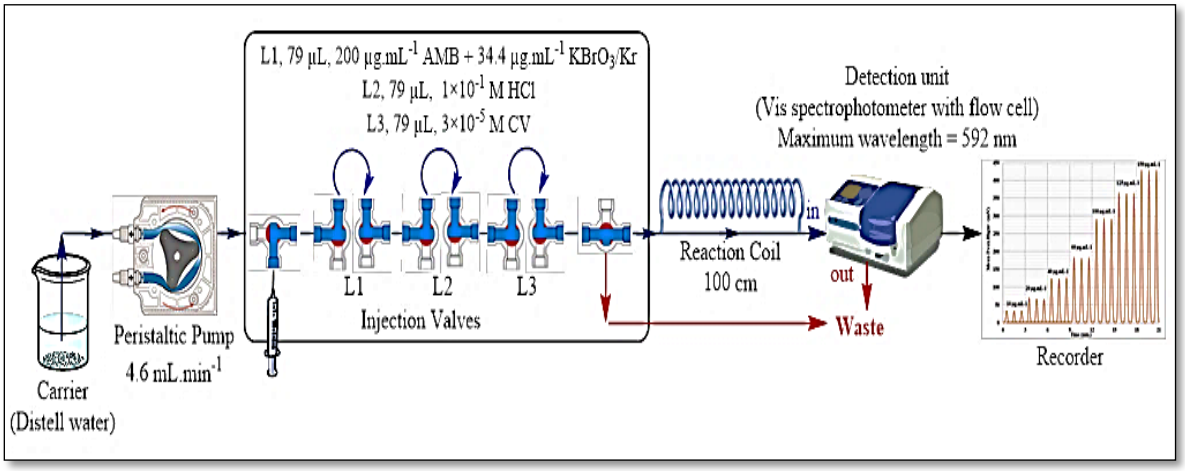


Figure 5. The developed CFIA system

3.2.2. Enhancement of the FIA system parameters that were developed

To achieve high sensitivity and maximal response, several physical and chemical factors were examined, including flow rate, reaction coil length, loop volume, injection time, and the concentrations of the oxidizing agent, reagent CV, and acid. To determine the ideal concentration of KBr: $KBrO_3$, a handmade injection valve was used to load several quantities of 6.87-41.25 µg/mL of 275 µg/mL into L1. According to **Figure 6A**, the absorbance value with the highest repeatability, as indicated by the peak height in mV (n=3), was 27.5 µg/mL (1 mL).

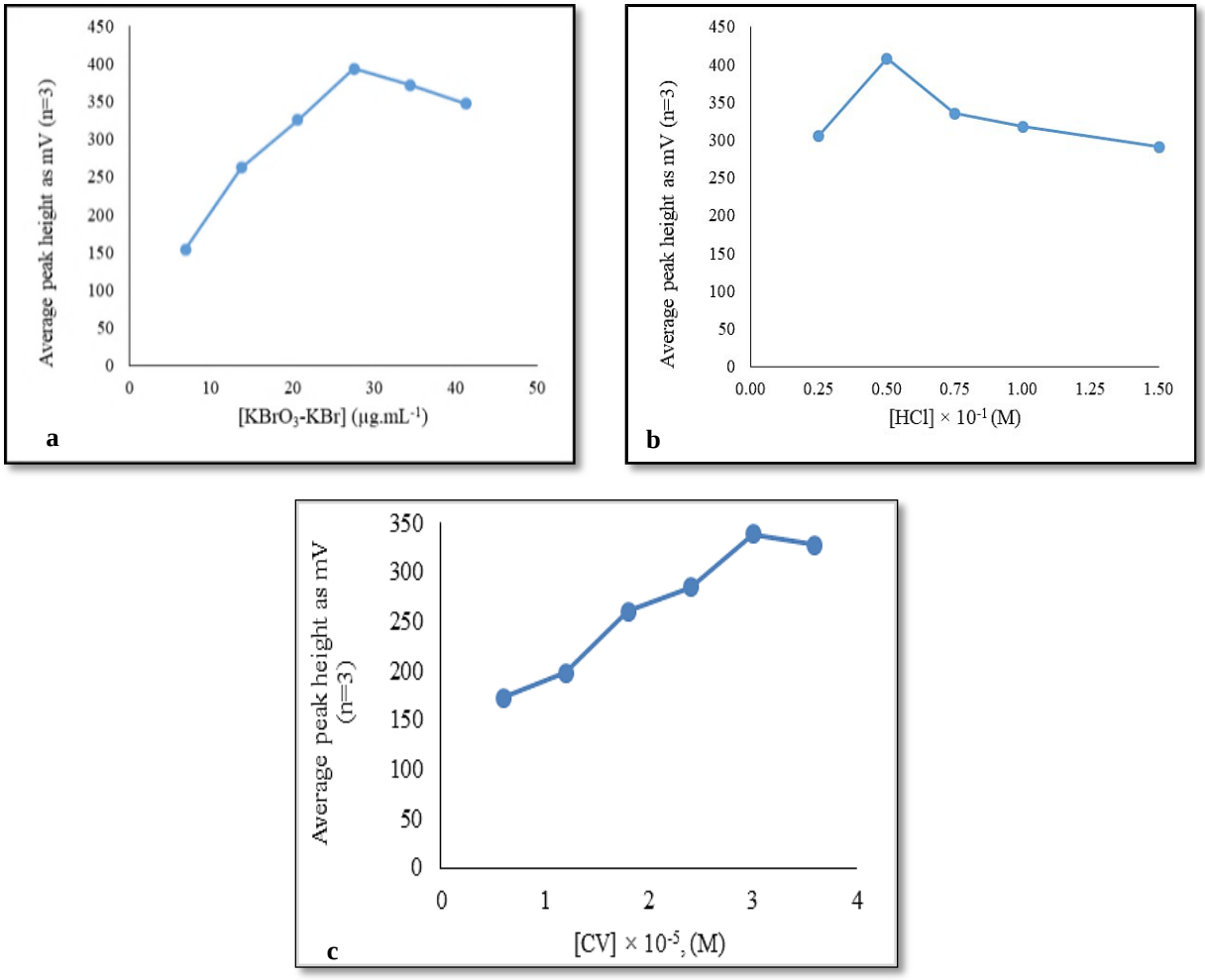


Figure 6. Effect of A- (KBr-$KBrO_3$), B- HCL, C- CV (AMB= 200 µg/mL)

To ascertain the optimal acid HCL concentration, a custom injection valve was used to load in L2 and inject various quantities 0.25×10^{-1}-1.5×10^{-1} M of 1M HCL Using a handmade injection valve for loading in (L2) the outcomes shown in **Figure 6B** showed that the absorbance value of 0.05 M (0.5 mL) provided The highest absorbance value, illustrated as peak height in mV (n=3). The ideal concentration of the reagent CV was examined by injecting different concentrations of 2.4×10^{-4} M, ranging from 0.000006 to 0.000036 M. The findings in **Figure 6C** showed that the absorbance value with the highest peak height (mV; n=3) was 3×10^{-5} M.

3.2.3. Selecting the optimal manifold unit

The optimal sequence, according to the results in **Figure 7**, was AMB and the oxidizing agent $KBrO_3$-KBr in the first loop, acid HCL in the second loop, and the reagent CV in the third loop.

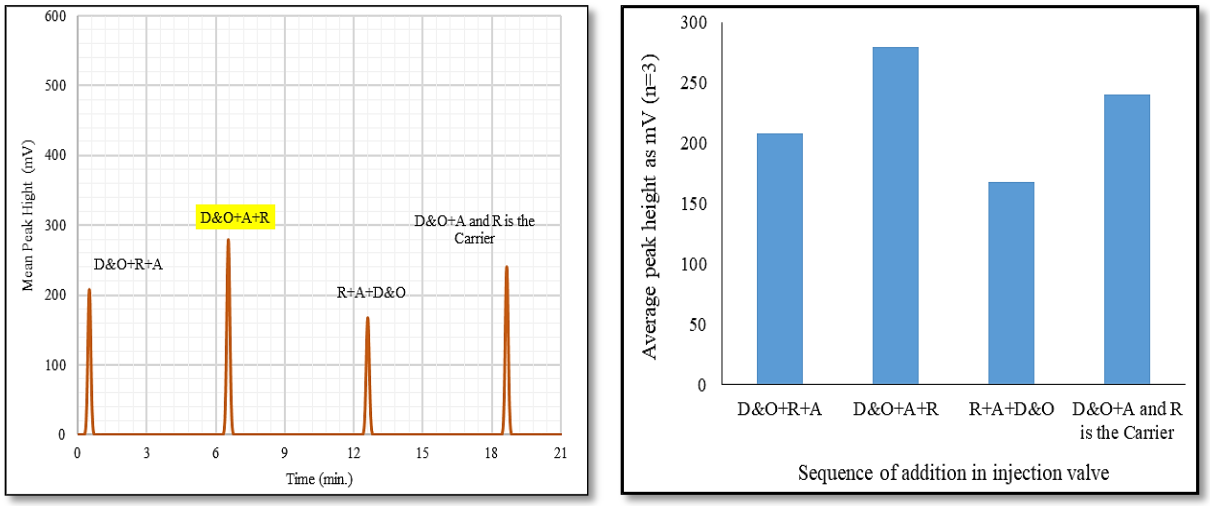


Figure 7. Effect of the sequence of chemical variables

3.2.4. Effect of the physical variables

3.2.4.1. Reaction coil and injected volume effects

The optimal reaction coil length for the AMB reaction was 100 cm, as illustrated in **Figure 8**. For the AMB-KBr /$KBrO_3$-HCL-CV reaction, the best loops for the AMB, oxidizing agents, acid, and reagent were 60 -40-40 cm (118-79-79 µL), as shown in **Figure 9**.

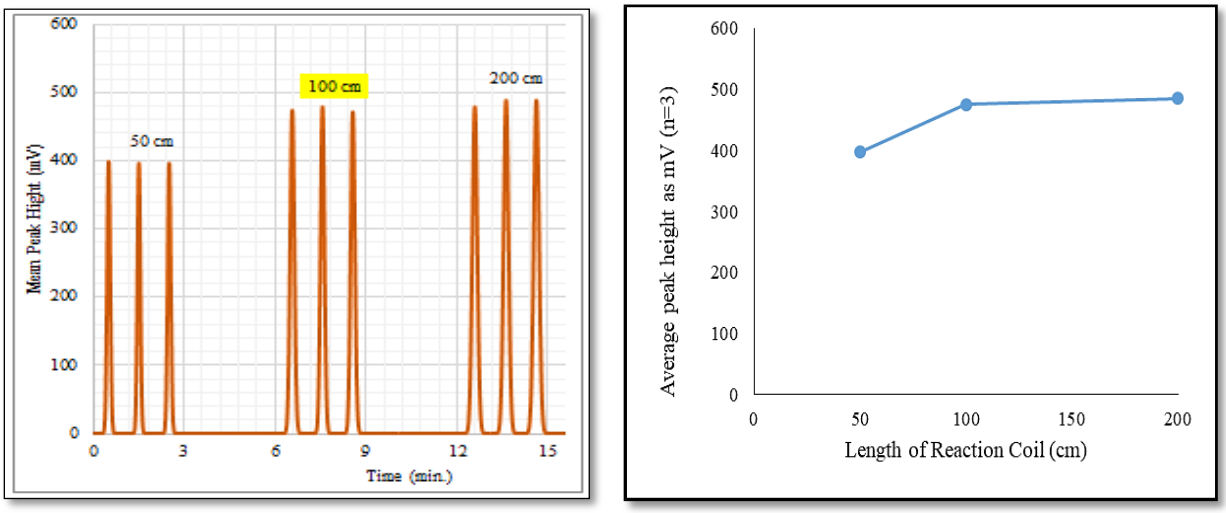


Figure 8. Reaction coil

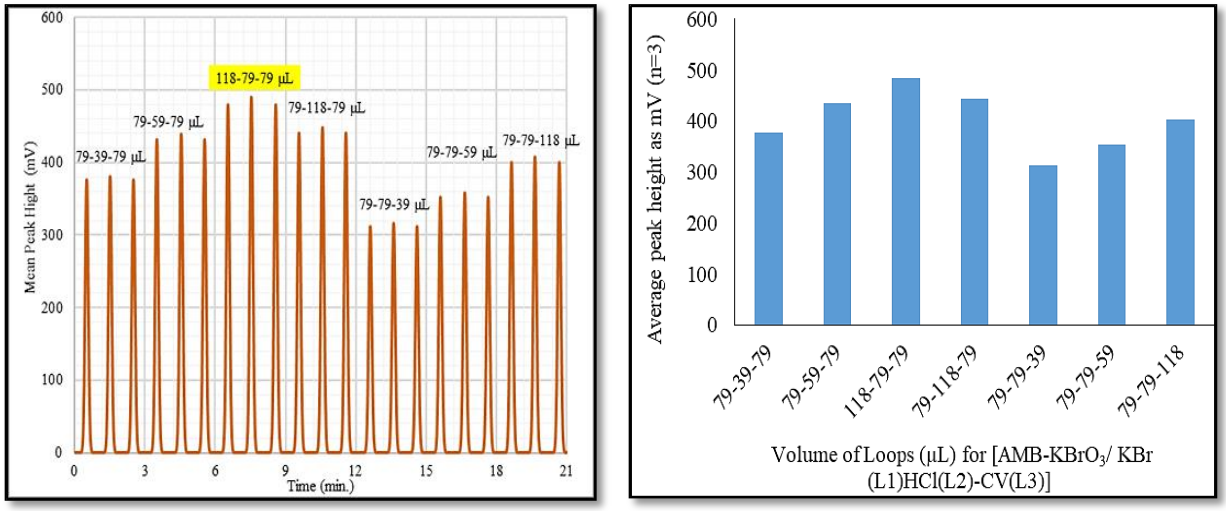


Figure 9. The impact of the volume injected

3.2.4.2. Flow rate's effect

One of the crucial components is the carrier current flow speed in the FIT, which significantly influences the results. Certain reactions occurred quickly, while others took longer. In this reaction, AMB-$KBrO_3$/KBr-HCl-CV, various flow rates were examined, and, as illustrated in **Figure 10**, the optimal flow rate was 7.79 mL/min, with a sample throughput of roughly 103 samples/h.

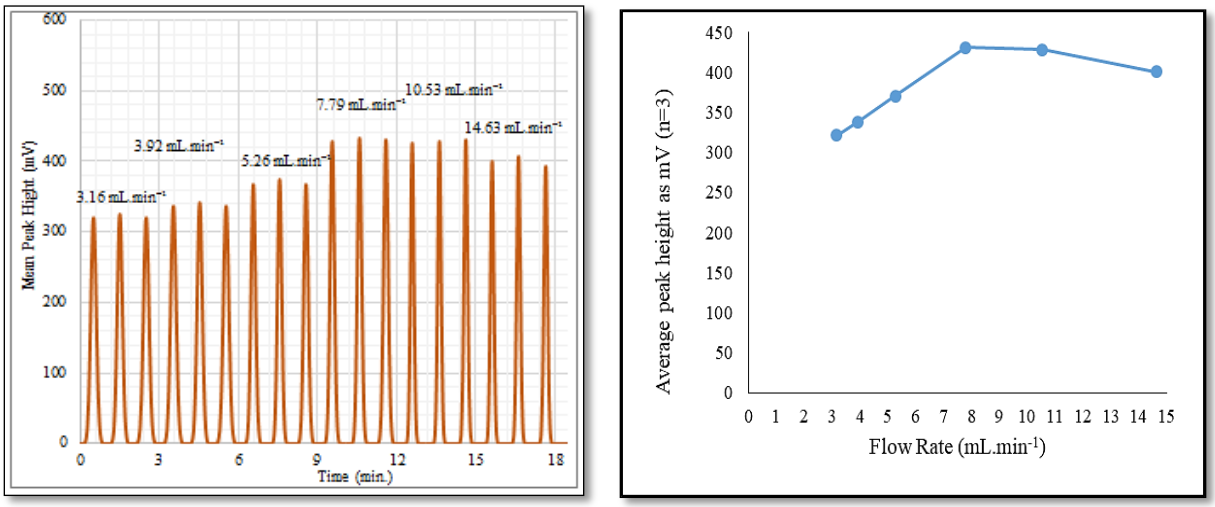


Figure 10. Effect of flow rate

3.2.4.3. Dispersion

One physical phenomenon in the FIA technique is dispersion, arising from interactions between the sample and the carrier stream, which spreads the sample throughout the solution under the influence of various concentration gradients. The success of FIA analysis is predicated on these three fundamental concepts. The following law was used to compute the dispersion:

$D = \frac{C_o}{C}$.

C_o: response before dilution is, although C is the response after dilution. The dispersion for AMB was (1.37, 1.36) as shown in **Table 3** and **Figure 11**. The study involved 2 experiments. In the first experiment, all chemicals were mixed in a beaker and then introduced as a carrier stream. Through an FI system to generate a fixed response represented by (Co). Another process, AMB, KBr-$KBrO_3$, and CV were administered L1, L2, and L3 injections, respectively. Materials are

delivered to the mixing zone using the injected component and DW as carriers, then transported there[24].

Table 3. ADB's dispersion value

Conc. (µg/mL)	C_o		C		D
	Length of Peake (cm)	Peak Height (mV)	Length of Peake (cm)	Peak Height (mV)	
50 µg/mL	2.6	208	1.90	152	1.37
150 µg/mL	6.3	504	4.62	369.6	1.36

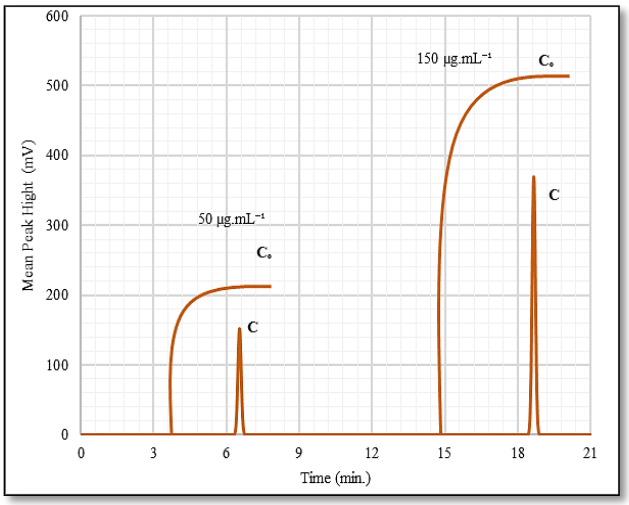


Figure 11. Dispersion of AMB-CV reaction

3.3. Calibration graph of AMB-CV reaction

A series of AMB concentrations ranging from 5 to 350 µg/mL with KBr-$KBrO_3$, HCL, and CV introduced into the FIA system after all optimal conditions were verbally confirmed. This made it possible to identify the ideal range of AMB concentrations that may be employed with this technique; as shown in **Figure 12** and **Table 4**, the ideal concentration range is between 10 and 250 µg/mL.

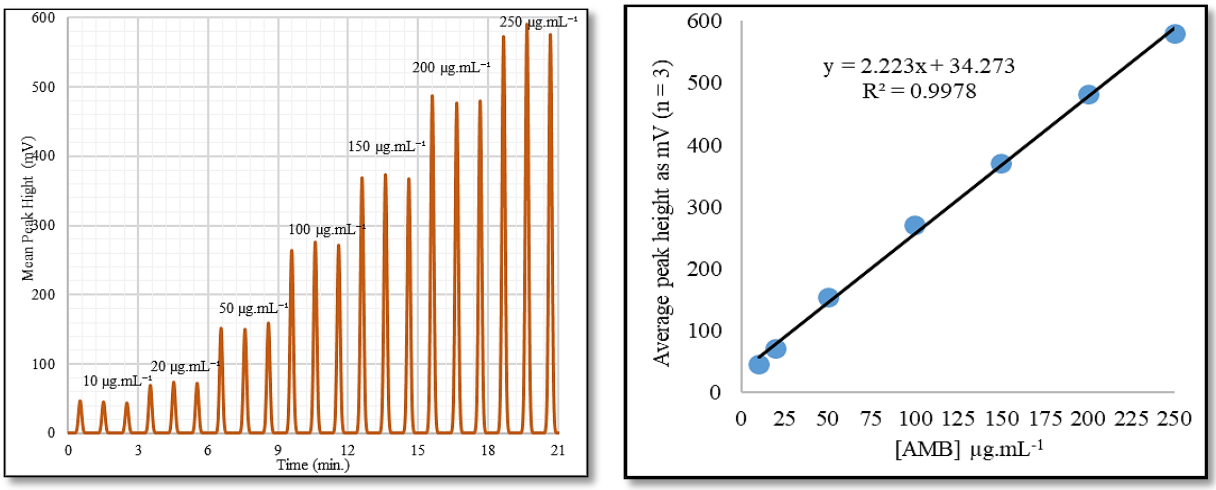


Figure 12. AMB calibration graph

Table 4. AMB-CV System calibration curve

Conc. (µg/mL)	Average response ($\bar{y}$) (mV)	SD	RSD%	S.E.M
10	45	1.6095	3.54	45.50 ± 4.0
20	72	2.3681	3.29	71.98 ± 5.88
50	154	4.3000	2.79	153.87 ± 10.68
100	271	4.4210	1.63	270.53 ± 10.98
150	370	2.7781	0.75	370.34 ± 6.90
200	480	2.8095	0.58	480.27 ± 6.97
250	578	2.7713	0.48	577.60 ± 6.88

3.4. Analysis of variation (ANOVA) and repeatability

Table 5 show that calculation summation of squares (ssqb) of the error (between groups) by the equation: $ssqb = \sum n_i(\bar{y}_i - \bar{y}_{GM})^2$ where; $\bar{y}_i$ is the responses, $\bar{y}_{GM}$ is the grand mean of $\bar{y}_i$ and $\bar{y}_i$-$\hat{y}$ ($\hat{y}$ appraiser response) and n_i is the number of responses for (1) degree of freedom (number of columns^{-1}). Calculation summation of squares (ssqw) of the regression (within groups) by the equation: $ssqw = \sum(n_i - 1)\ S_i^2$ where; S_i^2 is the variance for the degree of freedom (number of all readings ($\bar{y}_i$) and ($\bar{y}_i$-$\hat{y}$)-2), when dividing the (MS_1) by (MS_2) gets the value (F)[25,26].

Table 5. Variance analysis for FIA (AMB-CV) system

Source of Variation	Sum of squares(SS)	Df	Mean of squares MS	F	F crit
Between groups	278289.2277	1	278289.2277	13.17050013	4.747225347
Within groups	253556.8658	12	21129.73881		
Total	531846.0935	13			

$F_{crit.}$ (4.7472) << F (13.1705) so that it might be complete where the concentration of AMB and the signal obtained have a significant relationship. The method showed high repeatability, as revealed in **Table 6** and **Figure 13**.

Table 6. Repeatability of AMB-CV system

ADB-KBr /$KBrO_3$-HCL-CV						
AMB Conc. µg/mL	**Found**	**Error**	**Rec%**	**Erel%**	**SD**	**RSD%**
50	51.70	1.70	103.41	3.41	2.26	1.51
150	151.71	1.71	101.14	1.14	2.18	0.59

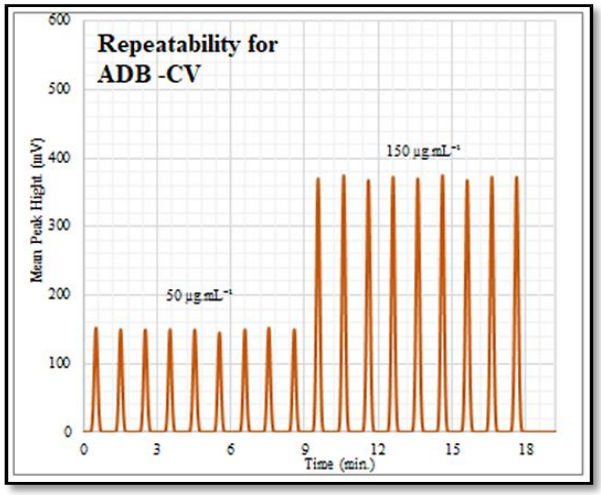


Figure 13. Repeatability of AMB-CV reaction

3.5. Method validation

The analytical characteristics of the developed method (CFIA/MZ), including DL, LOQ, relative standard deviation, correlation coefficient (r), linear range, recovery, and relative error, are shown in **Table 7**.

Table 7. Characteristics of the CFIA system's calibration graph and assessment of the (AMB) product

Variable	CFIA/MZ	Spectrophotometric
Regression equation	y = 2.223x + 34.273	y = 0.0083x+0.06
Linearity range (µg.mL^{-1})	10-250	5-90
Average of recovery (Rec.%)	99.810	98.191
Average of Relative Error (E_{rel}%)	-0.190	-1.809
Average of Relative standard deviation (RSD%)	2.418	2.306
Slope (b)	2.2230	0.0083
Intercept (a)	34.2730	0.0600
Linearity (R^2)	0.9978	0.9994
Correlation coefficient (r)	0.9989	0.9997
Standard deviation of slope (S_b)	0.0466	0.0001
Standard deviation of intercept (S_a)	6.5390	0.0050
Detection Limit (DL)	2.4689	0.4620
Limit of quantification (LOQ)	8.2296	1.5399
Sample frequency (sample /hr)	103	-
Standard deviation of the residuals ($S_{y/x}$)	10.5261	0.0077
Confidence limit of slope (b)	2.22 ± 0.1141	-
Confidence limit of intercept	34.27± 16.0205	-

3.6. Chemical products applications

The results of the determination of chemical formulations containing AMB (as tablets) are presented in **Table 8**, following preparation of working solutions at different concentrations from the primary solution. The proposed method, compared with HPLC using F-test and t-test, showed that for AMB-KBr/$KBrO_3$-HCl-CV, the computed F-test values were 0.0702 and 3.2897, and the t-test values were 0.1739 and 0.9802, respectively.

Table 8. Determination of AMB as tablet

Industrial application	Proposed method					Official method				
	Conc. of D µg/mL		E_{rel}%	Rec.%	RSD%	Conc. of D µg/mL		E_{rel}%	Rec.%	RSD%
	Present	Found				Present	Found			
Amlodipine	50	50.05	0.10	100.10	0.86	50	50.42	0.84	100.84	1.02
	20	20.23	1.15	101.15	0.95	20	20.25	1.25	101.25	1.34
Amlodipine-accord	50	49.76	-0.48	99.52	0.78	50	50.15	0.30	100.30	1.21
	20	19.87	-0.65	99.35	1.40	20	20.41	2.05	102.05	0.94
Amaday ajanta	50	50.09	0.18	100.18	0.53	50	49.11	-1.78	98.22	1.40
	20	19.23	-3.85	96.15	0.97	20	19.42	-2.90	97.10	2.29
Amlo-denk	50	49.93	-0.13	99.87	0.54	50	50.34	0.68	100.68	1.10
	20	19.95	-0.25	99.75	1.34	20	20.23	1.15	101.15	0.98
$t_{tab} = 2.45\ for\ n_1 = n_2 = 4, n_1 + n_2 - 2 = 6, at\ 95\%\ confidence\ level$ $F_{tab} = 9.28\ for\ n_1 - 1 = n_2 - 1 = 3, at\ 95\%\ confidence\ level$										

3.7. Biological sample

AMB at a concentration of 100 µg/mL was tested for precision and accuracy. Blood sample accuracy and precision were acceptable, as illustrated in **Table 9**.

Table 9. AMB evaluation employing the suggested CFIA/MZ technique in biological samples

Serum					Plasma				
AMB µg/mL		E_{rel}%	Rec%	RSD%	AMB µg/mL		E_{rel}%	Rec%	RSD%
Present µ	Found $\bar{x}$				Present µ	Found $\bar{x}$			
100	99.94	-0.0601	99.94	0.37	100	98.88	-1.1200	98.88	0.85
100	97.68	-2.3181	97.68	1.65	100	99.94	-0.0601	99.94	1.64
100	97.23	-2.7697	97.23	0.55	100	98.59	-1.4149	98.59	0.59
100	98.59	-1.4149	98.59	1.37	100	99.94	-0.0601	99.94	1.41
100	99.49	-0.5117	99.49	1.42	100	100.17	0.1657	100.17	1.01
100	100.39	0.3915	100.39	1.53	100	101.75	1.7463	101.75	1.77
100	100.84	0.8431	100.84	0.50	100	102.20	2.1979	102.20	1.49

3.8. Investigation of interferences

The selectivity of the proposed approach was assessed by examining potential interferences, as shown in the following Table. A sample of pure 100 µg/mL AMB that had been examined with 50, 100, and 200 µg/mL quantity of specific interferences was analyzed using three excipients. The allowed recovery range of 95-105% in the data shown in **Table 10** indicates that there were no disruptions throughout the AMB calculation using the FIA method.

Table 10. Interferences affect the AMB estimation

Interference	Interference concentration µg/mL	Present concentration of D µg/mL	Found concentration of D µg/mL	E_{rel}%	Rec%
Standard	-	100	101	1.28	101.28
Sucrose	50	100	101	0.60	100.60
	100	100	100	-0.21	99.79
	200	100	98	-2.26	97.74
Cellulose	50	100	98	-1.69	98.31
	100	100	101	0.59	100.59
	200	100	97	-3.37	96.63
Lactose	50	100	97	-3.23	96.77
	100	100	97	-2.96	97.04
	200	100	103	3.00	103.00
Glucose	50	100	102	1.54	101.54
	100	100	98	-1.75	98.25
	200	100	98	-1.96	98.04
Sodium citrate	50	100	98	-2.34	97.66
	100	100	101	0.77	100.77
	200	100	102	2.36	102.36

4. Discussion

The present study focused on the development and evaluation of a FIA method for quantitative determination of AMB, which based on oxidation of drug with a potassium bromide/ bromate mixture in an acidic medium and its reaction with a violet dye, the calibration curve of AMB show good linearity within the concentration range (10-250 µg/mL), with a high correlation coefficient R2 (0.9989), indicating a strong relationship between the analyte concentration and the measured response. The low relative standard deviation (RSD%) values obtained from replicate measurements indicate good precision and repeatability of the method. The limit of detection (LOD) and limit of quantification (LOQ) values were sufficiently low (2.4689 and 8.2296), indicating that the proposed method is sensitive enough for determining AMB at low concentrations. The FIA method offers enhanced sensitivity due to efficient mixing and controlled reaction conditions. Accuracy studies, expressed as recovery percentages, yielded satisfactory results, with recoveries approaching 100%[27], analysis of variance shows that Fcrit. (4.7472) << F (13.1705) so it may be complete where there is an important relationship between the concentration of AMB and the signal obtained, at a 95% confidence level and n-2 degrees of freedom[28,29]. This indicates that the method is accurate and free from significant systematic errors.

Furthermore, common excipients present in chemical formulations did not cause significant interference, demonstrating the selectivity of the proposed method. One of the main advantages of the FIA technique is its high sample throughput and low reagent consumption. The short analysis time per sample makes the method suitable for routine quality control laboratories. Additionally, FIA's automation capabilities reduce human error and improve reproducibility. Compared with previously reported methods for AMB determination, the proposed FIA method exhibits comparable or superior performance in precision, accuracy, and analysis time. Therefore, it can be considered an effective alternative for determining AMB in pharmaceutical preparations.

5. Conclusion

In the current study, an FIA method was developed and successfully applied to determine AMB. The results of this study demonstrated that the proposed method exhibits good linearity over the studied concentration range, indicating its suitability for quantitative analysis. The method exhibited acceptable precision and accuracy, as evidenced by low relative standard deviations and high recovery percentages. In addition, the presence of common excipients did not cause significant interference, reflecting the selectivity of the proposed method. The FIA method offers several advantages, including short analysis time, simplicity, and low reagent consumption. These characteristics make the method appropriate for routine analysis of chemical materials. The results obtained indicate that the proposed method is a reliable and efficient alternative to conventional analytical methods for determining AMB in chemical preparations.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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