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DEVELOPMENT AND VALIDATION OF METHOD FOR SIMULTANEOUS ESTIMATION OF DROTAVERINE AND ACECLOFENAC IN BULK AND FINISHED DOSAGE FORM BY USING UV SPECTROPHOTOMETER

[1]Uday Deokate, [2]Priya Mijgar, [3]Sankalp Chavadikar, [4]Seema, Kurhe
[1]Associate Professor, Government college of Pharmacy, Chhatrapati Sambhajinagar, [2]Research Scholar, Government college of Pharmacy, Chhatrapati Sambhajinagar, [3]Research Scholar, Government college of Pharmacy, Chhatrapati Sambhajinagar, [4]Research Scholar, Government college of Pharmacy, Chhatrapati Sambhajinagar,
[1]Pharmaceutical chemistry, Research Scholar, Government college of Pharmacy, Chhatrapati Sambhajinagar, India

ABSTRACT:

This study aimed to develop and validate a simultaneous UV spectrophotometric method for the analysis of Drotaverine HCl and Aceclofenac. The method is based on the simultaneous equation principle, which involves the measurement of absorbance at the maximum wavelengths of the respective drugs. The method was validated for linearity, accuracy, repeatability, intermediate precision, and robustness according to ICH and USP guidelines.

Background:

As firstly simultaneous equation method is cost-effective and time-saving. Drotaverine antispasmodic drug it has an apparent and prolonged action on smooth muscles of internal organs and blood vessels and it moderately decreases arterial blood pressure, increases cardiac output (minute volume of heart), and have some anti-arrhythmic potential.

Aceclofenac is a phenylacetic acid derivative and a non-steroidal anti-inflammatory drug (NSAID) that acts via COX-2 inhibition. It regulates inflammatory mediators such as prostaglandin E2 (PGE2), IL-1β, and TNF-α through the arachidonic acid pathway.

Methods:

The study utilized UV spectrophotometry to simultaneously estimate Drotaverine HCl and Aceclofenac using the simultaneous equation method. Absorbance was measured at 234.0 nm and 276.0 nm, the respective λmax of the drugs. The method was validated as per ICH and USP guidelines for linearity, accuracy, precision, repeatability, intermediate precision, and robustness.

Result:

The UV spectrophotometric method showed maximum absorbance at 234.0 nm for Drotaverine HCl and 276.0 nm for Aceclofenac, using phosphate buffer as the diluent. The method demonstrated good linearity ($r^2 > 0.999$), accuracy (98–102%), and robustness. Precision was confirmed with %RSD values below 2%.

Conclusion:
The developed robust and accurate method which can be used to estimation of Drotaverine Hcl and Aceclofenac in tablet dosage form. The limits of quantification of this method cover the concentration range recommended by USP (80-120%) which justifies the application of this method.

Keywords: Drotaverine HCl, Aceclofenac, UV spectrophotometry, Simultaneous equation method, Method validation

1. INTRODUCTION:

UV-visible spectrophotometric analysis is widely used due to its simplicity, accessibility, and broad applicability in pharmaceutical analysis [1,2]. Method validation ensures reliability and reproducibility, minimizing variability caused by factors such as instrumentation, environmental conditions, and operator handling. According to USP and ICH guidelines, an analytical method should be validated for parameters like linearity, precision, accuracy, specificity, quantitation limit, robustness, and ruggedness[3,4]. There are some methods for estimation of multicomponent for UV visible spectrophotometry as: Simultaneous equation method, Area Under Curve (AUC) Method, Absorbance Ratio Method (Q – ANALYSIS**).** Strategy for method development in UV absorption spectroscopy depend on literature survey, selection of solvent, optimization of solvent, selection of detection wavelength, study of Beer-Lambert law, validate method in routine laboratory[5,6].

Study of Beer -Lambert law:

The Beer-Lambert Law establishes a linear relationship between:

Absorbance (A), Concentration(C) of the solute, Path length (L) of the sample cell, Molar absorptivity (E or ε)

The equation is,

$$A = \varepsilon C L$$

Or using logarithmic form:

$$A = \log(I_0/I)$$

Extended Concepts:

$$A = abc$$

Where a is absorptivity, b is path length, and c is concentration. If a is constant, then absorbance depends on b and c linearly. Specific absorbance (A1% 1cm): This is the absorbance of a 1% w/v solution (1g/100ml) in a 1 cm path length cuvette. Conversion Formula: To convert A1% 1cm to molar absorptivity: ε = A1% 1cm × Molecular Weight / 10 [2,7]. The Beer-Lambert Law provides a fundamental quantitative relationship between the absorbance of a solution and its concentration, enabling accurate spectrophotometric analysis[7,8]. This study investigates the application of Beer-Lambert Law for two pharmaceutical compounds, Drotaverine and Aceclofenac, using UV-Visible spectrophotometry [9,10]. The linear correlation between absorbance and concentration allows for the determination of unknown concentrations based on measured optical density. Solution of known concentrations of Drotaverine HCL and Aceclofenac were prepared and analyzed using a UV-visible spectrophotometer. Absorbance values were recorded at their respective wavelengths of maximum absorbance (λ max). A 1 cm path length cuvette was used for all measurements. Calibration curves were plotted to assess linearity [11,12,13].

Development of simultaneous equation:

If a sample contains two absorbing drugs (x and y) each of which absorbs at the λ max of the other, it may be possible to determine both drugs by the technique of simultaneous equation (**Vierordt's method**) [13,14,15] provided that certain criteria apply the information required is,

- The absorptivity's of x at λ1 and λ2, ax1 and ax2 respectively
- The absorptivity of y at λ1 and λ2, ay1 and ay2 respectively
- The absorbance of the diluted samples at λ1 and λ2, A1 and A2 respectively.

Let Cx and Cy be the concentration of x and y respectively in the diluted samples.

Two equations are constructed based upon the fact that at λ1, the absorbance of the mixture is the sum of the individual absorbance of x and y.

A1= ax1bCx + ay1bC (1)

A2= ax2bCx + ay2bCy (2)

For measurements in 1cm cells b=1cm.Rearrange equation 2

Cy = (A2-ax2Cx)/ay2 (3)

Substituting for Cy in eq. (1) and rearranging gives

Cx = (A2ay2-A1ay2)/(ax2ay2-ax2-ay2 (4)

Cy = (A2ax2-A2ax1)/(ax2ay1-ax2ay2 (5)

Criteria for obtaining maximum precision, based upon absorbance ratios, have been suggested that place limits on the relative concentrations of the components of the mixture. The criteria are that the ratios and should lie outside the range 0.1-2.0 for the precise determination of y and x respectively. These criteria are satisfied only when the λ max of the two components reasonably dissimilar and if the two components do not interact chemically, thereby neglating the initial assumption that the total absorbance is the sum of the individual absorbance. Simultaneous equation method was developed for simultaneous determination of several mixture scanning of drugs and determination of working wavelengths [15,16].

2. MATERIALS AND METHODS:

Table 1: Name of drug and supplier

Drug	Supplier
Drotaverine Hcl	**Yarrow pharma**
Aceclofenac	**Swapnroop, Labs Aurangabad**

Table 2: Reagents and chemical

Reagent and Chemical	Source	Specification
Methanol	**Fischer scientific**	**HPLC grade**
Hydrochloric Acid	**Qualigens**	**Analytical grade**
Sodium hydroxide	**Qualigens**	**Analytical grade**
Hydrogen peroxide	**Fischer scientific**	**Analytical grade**

2.1 Drug's Identification and Characterization

The FTIR spectrum were recorded using SHIMADZU PRESTIGE MODEL FTIR INSTRUMENT and its interpretation was carried out.

2.2 Selection of Common Solvent

Methanol of analytical reagent grade was selected as common solvent for developing spectral characteristics of drug. The selection was made after assessing the solubility of both the drugs in different solvents like water, dimethyl formamide, methanol etc.

2.3 Preparation of Stock Solution

2.3.1 Drotaverine hydrochloride stock solution:

An accurately weighed of DRV HCL 10 mg was transferred to the 10 ml volumetric flask and dissolved in methanol. The volume was made up to the mark with the methanol to get concentration of 1000 µg/ml. Further 1ml of this solution was taken and diluted in 10 ml volumetric flask up to mark to get concentration of 100 µg /ml. Further 1 ml of this solution was taken and diluted in 10 ml volumetric flask up to mark to get concentration of 10 µg /ml [17,18]

2.3.2 Aceclofenac stock solution:

An accurately weighed of ACF 10 mg was transferred to the 10 ml volumetric flask and dissolved in methanol. The volume was made up to the mark with the methanol to get concentration of 1000µg/ml. Further 1ml of this solution was taken and diluted in10ml volumetric flask upto mark to get concentration of 100µg/ml. Further 1ml of this solution was taken and diluted in 10 ml volumetric flask up to mark to get concentration of 10µg/ml [13,14]

2.4 Absorptivity Value

Aliquot portion of DRV HCL from stock solution were transferred to five 10 ml volumetric flask; volume was adjusted to mark to obtain the concentration of 10 µg/ml. Similarly, aliquot portions from ACF stock solution were transferred to five 10 ml volumetric flask; volume was adjusted to mark to obtain concentration of 10 µg/ml. Absorbance of these solutions were recorded at two wavelength 234.0 nm and 276.0 nm[13].

2.5 Application of Simultaneous Eq In Laboratory:

Application of proposed method for simultaneous estimation of drugs in laboratory mixture, In order to see the feasibility of proposed method for simultaneous estimation of DRV HCL and ACF in marketed pharmaceutical formulations, the method was first tried for estimation of drugs in standard laboratory mixture [5]. Accurately weighed 10 mg DRV HCL and 10 mg ACF were transferred to 10 ml volumetric flask. Both the drugs were dissolved in methanol to give stock solution of concentration 1000 µg/ml. Appropriate aliquot portion of DRV HCL (1ml) was transferred to10 ml volumetric flask and diluted with methanol to obtain the concentration 100 µg/ml of DRV HCL and further appropriate aliquot portion of DRV HCL (1 ml) was transferred to 10ml volumetric flask and diluted with methanol to obtain the concentration 10 µg/ml of DRV HCL[16,17]. Similarly, Appropriate aliquot portion of ACF (1 ml) was transferred to10 ml volumetric flask and diluted with methanol to obtain the concentration 100 µg/ml of ACF and further appropriate aliquot portion of ACF (1 ml) was transferred to 10ml volumetric flask and diluted with methanol to obtain the concentration 10 µg/ml of ACF Absorbance was measured at 234.0 nm and 276.0 nm against methanol solvent as blank. From the absorptivity values, the concentration of drugs in the standard laboratory mixture was determined by the equation. [19,20]

$$Cx = A2.ay1 - A1.ay2 / ax2.ay1 - ax1.ay2 \qquad (6)$$
$$Cy = A1.ay1 - A2.ay2 / ax2.ay1 - ax1.ay2 \qquad (7)$$

Cx and Cy = Concentration of DRV HCL and ACF in 10 µg/ml and 10 µg/ml respectively
A1 and A2 = Absorbance of mixed standard at 234.0nm and 276.0nm, respectively
ax1 = E (1%, 1cm) of DRV HCL at 234.0nm = **0.0957**
ax2 = E (1%, 1cm) of DRV HCL at 276.0nm = **0.0404**
ay1 = E (1%, 1cm) of ACF at 234.0nm = **0.0508**
ay2 = E (1%, 1cm) of ACF at 276.0nm = **0.0842**

$$Cx = A2 \times ay1 - A1 \times ay2 / ax2 \times ay1 - ax1 \times ay2$$
$$Cx = A2 \times (0.0508) - A1 \times (0.0842) / (0.0842 \times 0.0508) - (0.0957 \times 0.0842)$$
$$Cx = A2 \times (0.0508) - A1 \times (0.0842) / -0.003780$$

$$Cy = A1 \times ay1 - A2 \times ay2 / ax2 \times ay1 - ax1 \times ay2$$
$$Cy = A1 \times (0.0508) - A2 \times (0.0842) / (0.0404 \times 0.0508) - (0.0957 \times 0.0842)$$
$$Cy = A1 \times (0.0508) - A2 \times (0.0842) / -0.07852$$

By above study:

This spectrophotometric method uses two wavelengths to resolve the concentrations of DRV Hcl and ACF simultaneously using known absorptivity values. It's a classical application of the simultaneous equation method in UV spectroscopy for binary mixtures, showing it is effective for quality control or formulation studies

2.6 Application of Proposed Method For Simultaneous Estimation of Drugs In Tablets:

Twenty tablets were weighed and powdered. an accurately weighed quantity of tablet powder equivalent to about 80 mg DRV HCL and 100 mg ACF was transferred to 100 ml volumetric flask and 20 ml methanol was added to it. The solution was then sonicated for 10 minutes. A further 30 ml methanol was then added and the solution was again sonicated for another 15 minutes with intermittent shaking. The volume was made up to the 100ml mark with methanol. Solution was mixed and filtered through Whatman filter paper no. 41 (stock solution) which was used for estimation of ACF and DRV HCL. From this stock solution 1 ml of this solution was further diluted to 10 ml with methanol to obtain the final concentration of DRV HCL 80 µg/ml and ACF 100 µg/ml which was used for the estimation of DRV HCL and ACF respectively.[21]

2.7 Validation of Proposed Method:

2.7.1 Recovery studies:

To the pre analyzed sample solutions (2, 4, 6 µg/ml of DRV HCL and 2, 4, 6 µg/ml of ACF) a known amount of standard solution of (DRV HCL and ACF) were added at 80%, 100% and 120%. Then the % recovery was then calculated by using formula % Recovery = A / (B + C) x 100[21,22].

A = Total amount of drug estimated
B = Amount of drug found on preanalysed bases
C = Amount of pure drug added

2.8 Validation Parameter

2.8.1 Linearity

Standard stock solution was prepared by taking 10 mg of Drotaverine Hcl and Aceclofenac accurately and transferred separately in 100ml volumetric flasks. Both drugs were first dissolved in 10 ml of methanol using ultrasonicator and then final volume was made up to the mark with methanol to get 100 ug/ml concentrations. From this stock solution of Drotaverine 0.2,0.4,0.6,.08,1.0 and 1.2 ml of solution was transferred to 10 ml volumetric flask and make up volume with methanol to get concentration of 2-12 ppm. From this stock solution of Aceclofenac 0.2,0.4,0.6,.08,1.0 and 1.2 ml of solution was transferred to 10 ml volumetric flask and make up volume with methanol to get concentration of 2-12 ppm. The absorbances were plotted against the corresponding concentrations to obtain the calibration curve. [Fig.8,9] [22,23].

2.8.2 Range

The range of concentration was found to be ACF 2 -12 µg/ml and DRV HCL 2-12 µg/ml from the linearity data. The range of Drotaverine HCL and Aceclofenac decided according to coefficient of correlation (r^2) which was < 1 and calibration curve. [Fig. 8,9] [20,21].

2.8.3 Specificity And Selectivity

The solvent methanol and each drug solutions were scanned and UV spectra were obtained which indicate no interference of solvent. Specificity study was conducted by comparing the spectrum of tablet solution and that of standard solution. It was noted that there was no interference of the excipients in the formulations. [Fig.10] [13,21].

2.8.4 Accuracy

Accuracy of an analytical method is the closeness of the test results obtained by that of the true value. It was ascertained on the basis of recovery studies performed at different level of concentrations [Table 10,11] [21,22].

2.8.5 Precision

The precision of an analytical procedure expresses the closeness of agreement between a series of measurements obtained from multiple sampling of the same homogeneous sample under the prescribed conditions. Precision was determined intra-day and inter-day. Intra-day precision was determined by analyzing the six different sample of same concentration of 80 µg/ml of DRV HCL and 100 µg/ml of ACF drug solution for three times in the same day. Inter-day precision was determined by analyzing the same concentration at three different days. [Table 12,13] [23,25].

2.8.6 Limit Of Detection (LOD)

The limit of Detection of an individual analytical procedure is the lowest amount of analyte in a sample which can be detected but not necessarily quantitated as an exact value. Based on Residual Regression Line. [23,25]

LOD =3.3 × residual SD of Regression line/ Slop of line [7]

Based on SD of Y intercept of Regression Line, LOD = 3.3 × SD of Y intercept of regression line /Slop of line. [Table 15]

2.8.7 Limit of Quantitation (LOQ)

The limit of quantitation of an individual analytical procedure is the lowest amount of analyte in a sample which can be quantitatively determined with suitable precision and accuracy. [26,27].

Based on Residual Regression Line

LOQ= 10 × residual SD of Regression line/ Slop of line

Based on SD of Y intercept of Regression Line, LOQ = 10 × SD of Y intercept of regression line /Slop of line [Table 16]

2.8.8 Robustness

The purpose to ensure that the method consistently produces accurate and precise results even when there are slight variations in experimental conditions. The absorbance at different wavelength (λ max ± 1) indicate that the results were unaffected by the change in wavelength of detection. The insignificant differences in absorbance values demonstrated the good robust nature of the proposed method. We measured the absorbance and calculate concentrations. By evaluate the results in terms of % RSD (Relative Standard Deviation) as our results remain within acceptable limits (e.g., %RSD < 2%), the method is considered robust. [Table 17][27].

2.8.9 Ruggedness

Ruggedness parameter was carried out by changing in an analyst and changing in an instrument and % RSD was calculated. Results are provided further. [Table 18][27,28].

2.8.10 Recovery studies:

2.8.10.1 Drotaverine Hcl

To determine the accuracy of proposed method, recovery studies were carried out by adding different amounts (80%, 100%, 120%) of standard bulk sample of Drotaverine Hcl within the linearity range were taken and add to preanalyzed formulation of concentration 2µg, 4µg and 6µg and percentage recovery values are calculated. Test should be prepared in triplets at each spike level and assay should be done as per the ICH guildline. [6,8]

2.8.10.2 Aceclofenac

To determine the accuracy of proposed method, recovery studies were carried out by adding different amounts (80%, 100%, 120%) of standard bulk sample of Aceclofenac within the linearity range were taken and add to pre analyzed formulation of concentration 6µg, 8µg and 10µg and percentage recovery values are calculated Test should be prepared in triplets at each spike level and assay should be done as per the test method. [6,8,10]

3. RESULT AND DISCUSSIONS:

3.1 Drug's Identification and Characterization:

Identification and Characterization of Drug is done initially by using UV and IR spectroscopy

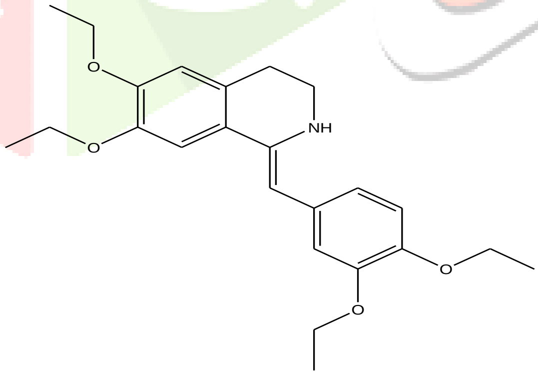

Fig.1: Structure of Drotaverin Hcl

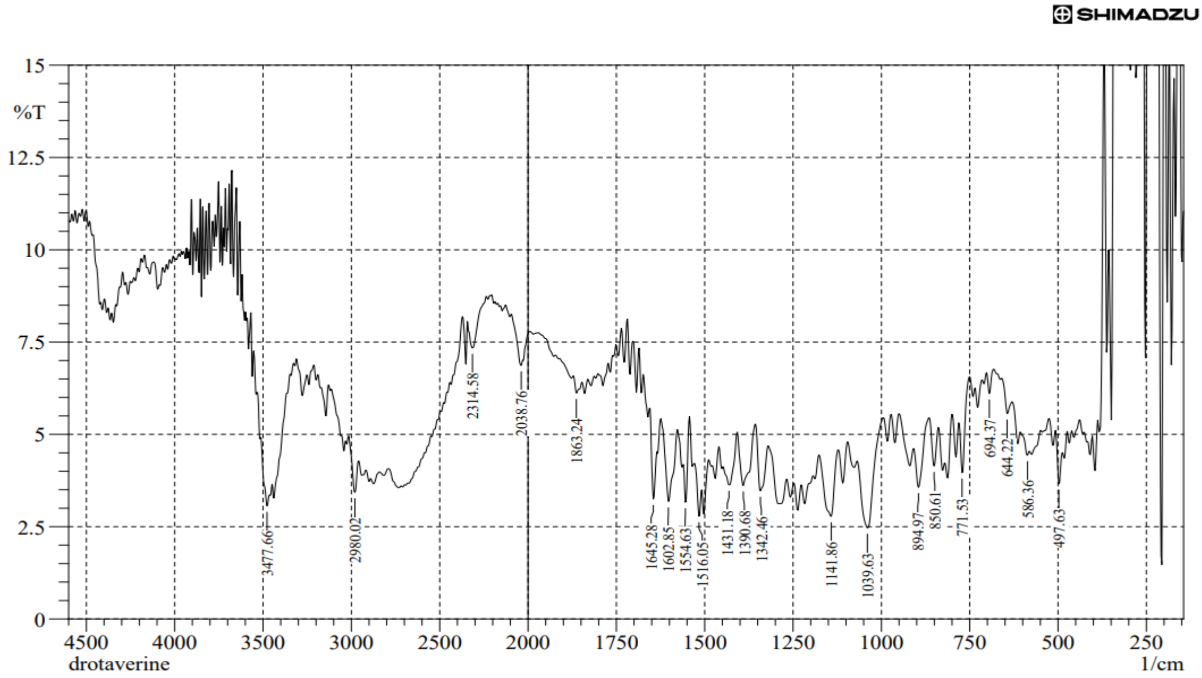

Fig.2: FTIR Spectra of Drotaverine

Table 3: Interpretation of DRV Hcl

Sr no.	Functional value	Reference value	Observed Value
1	C-H	3500-3100	3477.66
2	C-N	3300-3350	3312.22
3	C=N	1600-1500	1516.05
4	C-CH3	1515-1530	1554.63
5	C-H	675-30	694.37

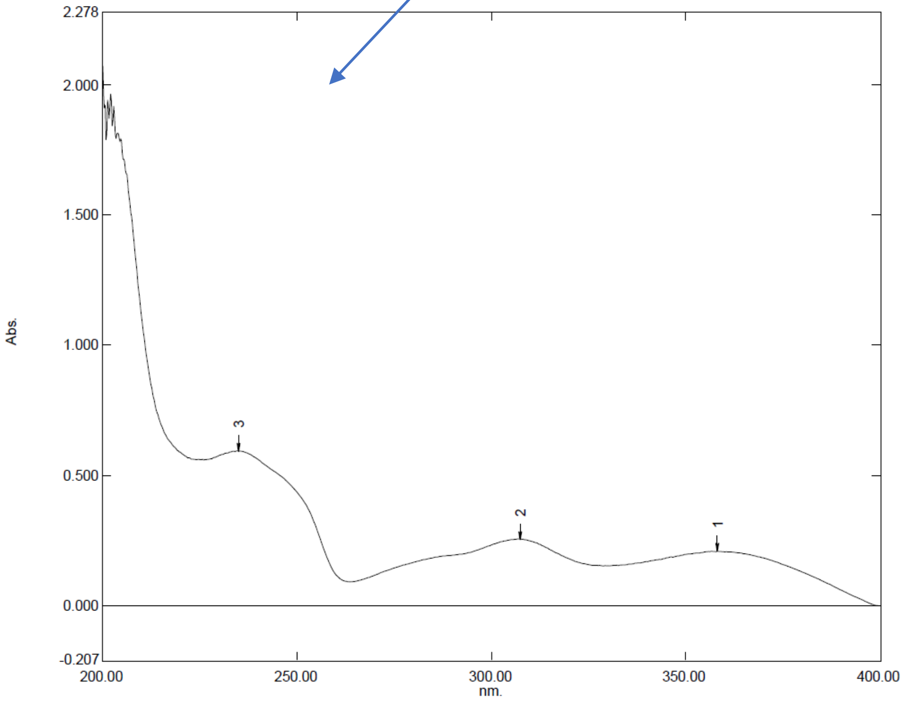

Fig.3: UV Spectra of Drotaverine

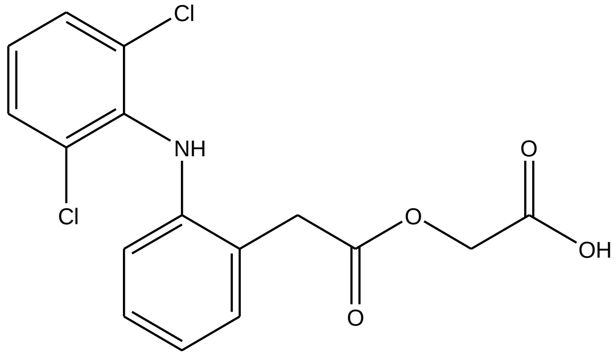

Fig. 4: Structure of Aceclofenac

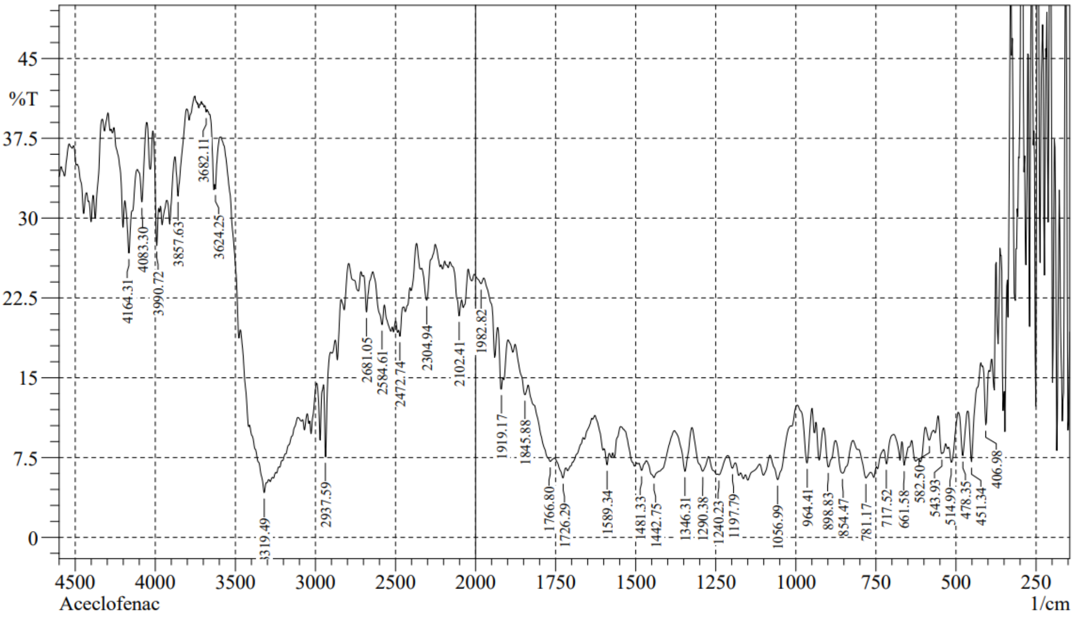

Fig. 5: FTIR Spectra of Aceclofenac

Table 4: Interpretation of Aceclofenac

Sr no.	Functional value	Reference value	Observed Value
1	C-H	3500-3100	3319.49
2	C-N	3300-3350	3624.25
3	C=N	1600-1500	1589.34
4	C-CH3	1515-1530	1589.34
5	C-H	675.30	661.58

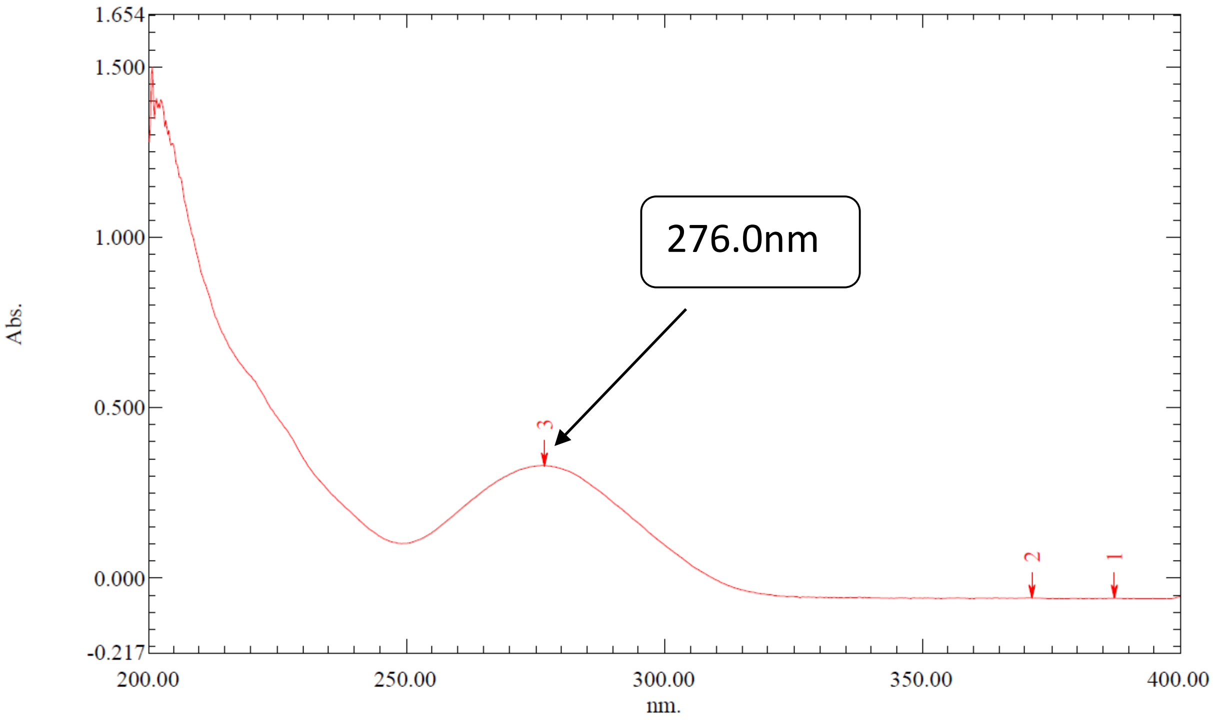

Fig. 6: UV Spectra of Aceclofenac

DRV (Drotaverine HCl) higher absorbance in the lower wavelength range and ACF (Aceclofenac)lower absorbance comparatively. The peak at 252.0 nm is clearly marked this is likely one of the λmax used for calculation in the simultaneous equation method.

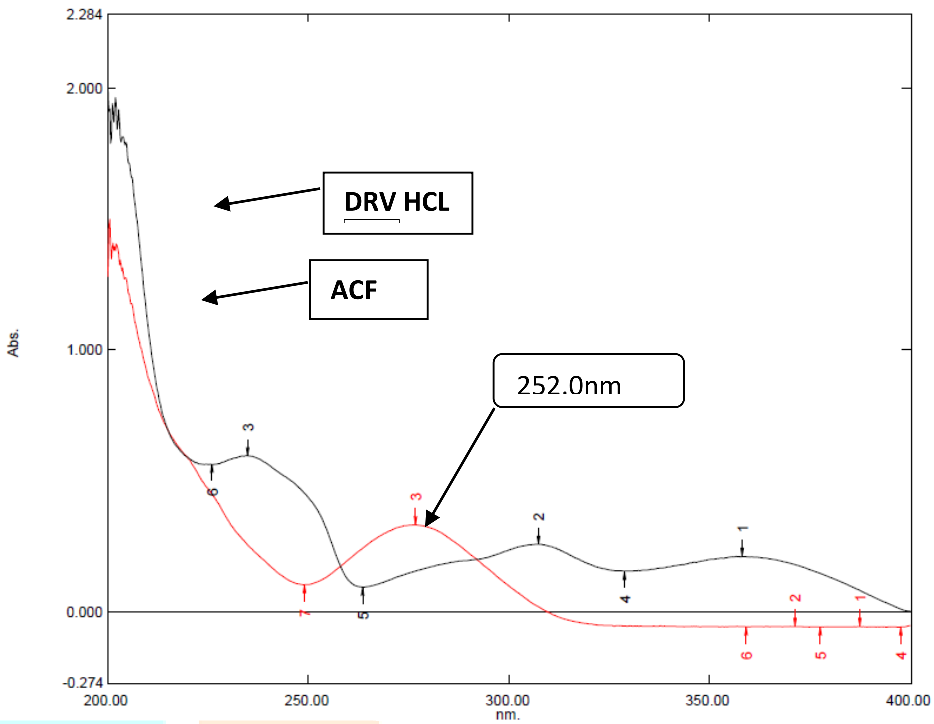

Fig. 7: Simultaneous graph of **Drotaverin Hcl** and **Aceclofenac**

3.2 Wavelength selection:

The wavelength of maximum absorbance for DRV Hcl and ACF were determined from the spectra of both molecules. Drotaverine HCL and ACF showed the absorbance of maximum absorbance at 234nm and 276 nm respectively. These wavelength values of maximum absorbance are like those used by the United state pharmacopoeia in dissolution analysis of Drotaverine HCL and ACF tablets which are 234 nm and 276 nm respectively.

3.3 Absorptivity Value:

Table 5: Absorptivity Value of Drotaverine and Aceclofenac

Sr.NO	Wavelength	Drotaverine Hcl		Aceclofenac	
		Absorbance	Absorptivity	Absorbance	Absorptivity
			ax1		ay1
1	234.0 nm	0.957	0.0957	0.404	0.0404
			ax2		ay2
2	276.0 nm	0.508	0.0508	0.842	0.0842

The absorptivity values (also called specific absorptivity or molar absorptivity) for Drotaverine HCl and

Aceclofenac at two selected wavelengths: 234.0 nm and 276.0 nm. respectively. This data is essential for performing the simultaneous equation method for their quantitative analysis using UV spectroscopy.

3.4 ACF and DRV HCL in standard Laboratory mixture:

Table 6: Estimation of ACF and DRV HCL in standard Laboratory mixture

Sr.no	**Amount present in (µg/ml)**		**Amount found in (µg/ml)**		**Amount Found in %**	
	ACF	**DRV Hcl**	**ACF**	**DRV Hcl**	**ACF**	**DRV Hcl**
1	10	8	9.67	7.78	96.7	97.25
2	10	8	9.8	7.95	98	99.37
3	10	8	9.69	7.68	96.9	96
4	10	8	97.1	7.87	97.1	98.3
5	10	8	99.7	8.02	99.7	100
				Mean	97.68	98.25
				SD	1.2336	1.6840
				% RSD	1.2629	1.7140

The result for simultaneous estimation of Drotaver Hcl and Aceclofenac which suggest that both DRV Hcl and ACF have recovery rates close to 100% indicating high accuracy of the method. The %RSD values are <2% for both drugs, suggesting that good precision of the method. The simultaneous equation method dveloped for ACF and DRV Hcl in the laboratory mixture is both accurate and precise.

3.5 ACF and DRV HCL in marketed tablet formulation:

Table 7: Estimation of DRV HCL and ACF in marketed tablet Formulation

Sr.no	**Amount present in (µg/ml)**		**Amount found in (µg/ml)**		**Amount Found in %**	
	ACF	**DRV Hcl**	**ACF**	**DRV Hcl**	**ACF**	**DRV Hcl**
1	10	8	9.92	7.9	99.2	98.75
2	10	8	9.84	7.8	98.4	97.5
3	10	8	9.60	7.71	96	96.37
4	10	8	9.97	7.63	99.7	95.37
5	10	8	9.78	7.54	97.8	94.25
				Mean	98.22	96.45
				SD	1.439	1.760
				% RSD	1.465	1.825

The result of estimation of DRV Hcl and ACF in marketed tablet formulation. ACF and DRV Hcl both show recovery values close to 100%, indicating that the method is accurate for marketed formulations. The % RSD values are below 2%, which confirms good repeatability and precision of the method for both drugs. The method is suitable for routine analysis of ACF and DRV HCl in commercially available formulations.

3.6 Linearity data of Drotaverine and Aceclofenac:

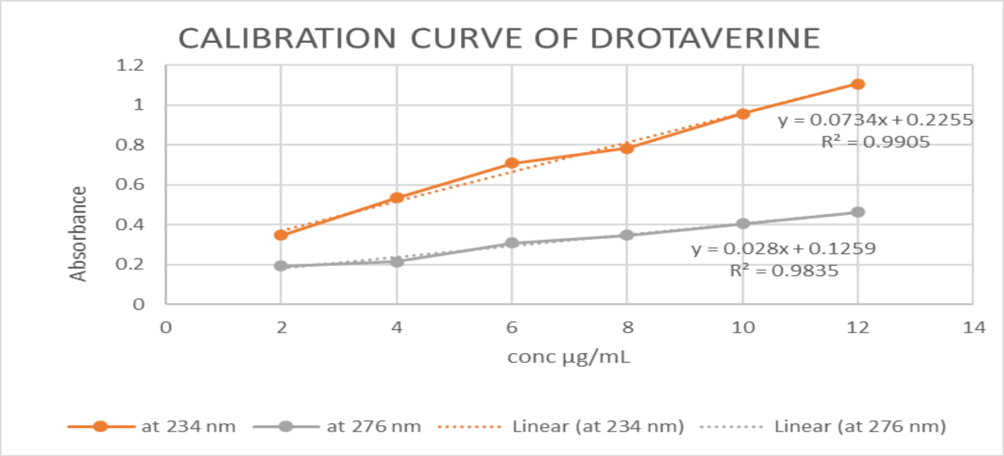

Fig.8: Calibration curve of Drotaverine

Table no.08: Calibration data of drotaverine

Sr.no.	Concentration	234.0 nm				276.0 nm			
		A	B	C	Average	A	B	C	Average
1	2	0.34	0.349	0.352	0.347	0.191	0.197	0.193	0.193
2	4	0.529	0.53	0.544	0.534	0.214	0.215	0.212	0.213
3	6	0.701	0.706	0.721	0.709	0.303	0.309	0.313	0.308
4	8	0.788	0.779	0.782	0.783	0.354	0.345	0.346	0.348
5	10	0.944	0.96	0.967	0.957	0.406	0.407	0.401	0.404
6	12	1.09	1.125	1.104	1.106	0.46	0.468	0.465	0.464
				Mean	0.739			**Mean**	0.322

				SD	0.275			**SD**	0.105
				%RSD	2.679			**%RSD**	3.040

3.6.1 Calibration Data of Drotaverine:

Above graph and table represents the absorbance values of Drotaverine HCl at two wavelengths (234.0 nm and 276.0 nm) across a series of concentrations, used to construct calibration curves for spectrophotometric analysis. The %RSD values for both wavelengths are below 5%, which is within acceptable limits for analytical methods, indicating good repeatability. These calibration curves can be used to estimate the concentration of Drotaverine Hcl in unknown samples using the simultaneous equation method, where absorbance values at both wavelengths are used for calculation.

3.6.2 Calibration Data of Aceclofenac:

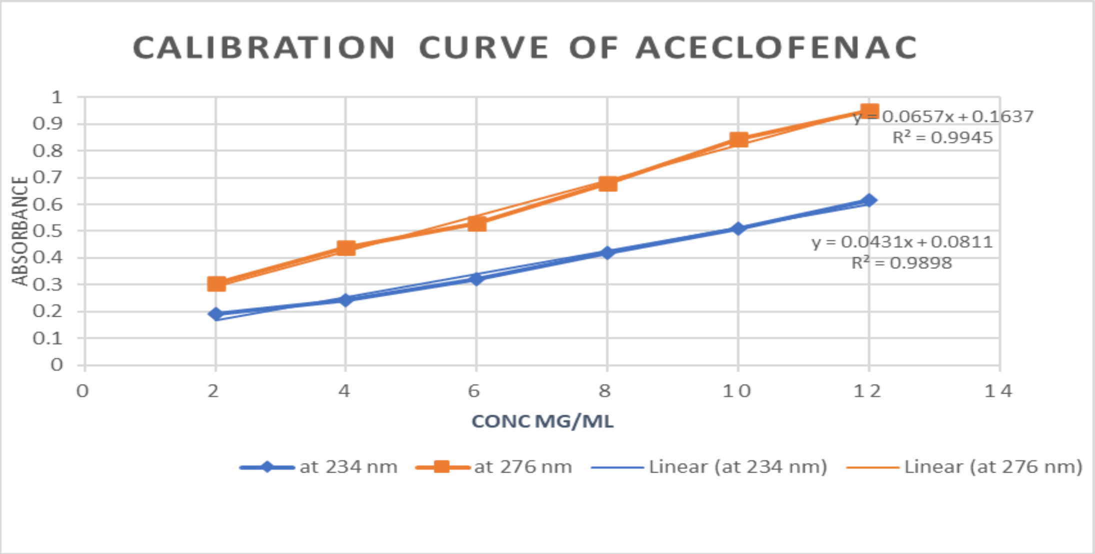

Fig. 9: Calibration curve of Aceclofenac

Table 09: Calibration data of Aceclofenac

Sr.no.	**Concentration**	**234.0 nm**				**276.0 nm**			
		A	B	C	**Average**	A	B	C	**Average**
1	2	0.194	0.189	0.188	0.190	0.301	0.301	0.309	0.303
2	4	0.242	0.249	0.241	0.244	0.435	0.437	0.439	0.437
3	6	0.323	0.318	0.318	0.319	0.52	0.528	0.536	0.528
4	8	0.422	0.419	0.417	0.419	0.679	0.675	0.685	0.679
5	10	0.515	0.505	0.505	0.508	0.833	0.843	0.852	0.842
6	12	0.622	0.613	0.61	0.615	0.958	0.952	0.941	0.950

				Mean	0.382			**Mean**	0.623
				SD	0.162			**SD**	0.246
				%RSD	2.362			**%RSD**	2.528

Above graph and table represents absorbance readings of Aceclofenac at two wavelengths (234.0 nm and 276.0 nm) across a range of concentrations. It is used to plot calibration curves for quantitative analysis using UV-Visible spectrophotometry. 234.0 nm used in the simultaneous equation method. 276.0 nm is the second wavelength used for simultaneous equation analysis. As the concentration of Aceclofenac increases, the absorbance values at both wavelengths increase linearly, confirming a linear response suitable for calibration curves. The %RSD values at both wavelengths are under 3%, which is considered acceptable for method validation. This indicates good precision and reproducibility. This calibration used to prepare calibration curves (absorbance vs. concentration) for Aceclofenac.These curves allow for the quantitative estimation of the drug in unknown samples, especially when using the simultaneous equation method in combination with drotaverine.

3.7 Specificity study:

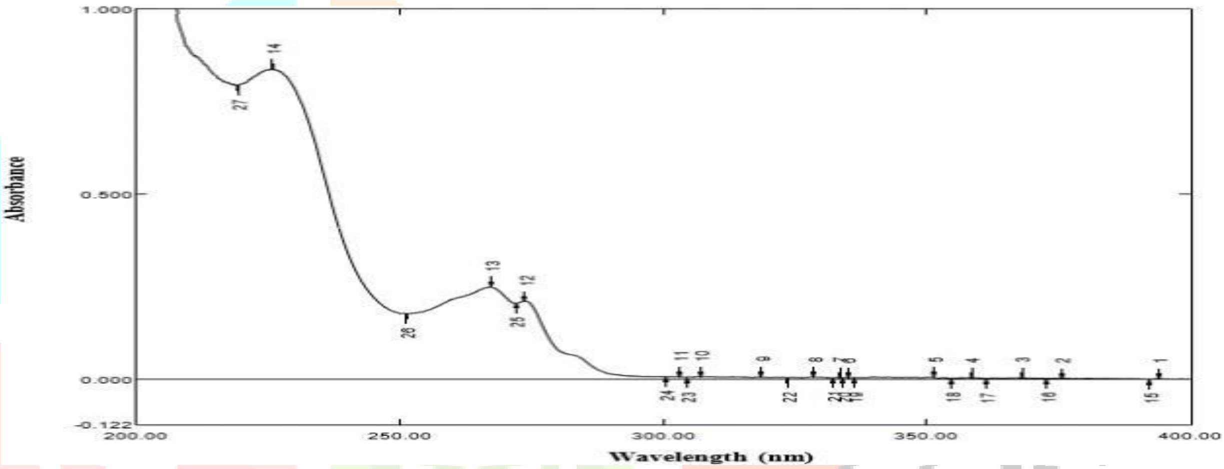

Fig. 10: Spectra of Sample in Methanol

Spectrum of Sample in Methanol: Purpose of this study is to evaluate the UV spectrum of the actual drug sample in methanol.The sample shows distinct peaks in the UV region, particularly around 234 nm and 276 nm, which aligns with earlier calibration data.These peaks indicate specific absorbance by the analyte, confirming its presence and identity.Which conclude that the drug sample gives well-defined absorption peaks.Since no interfering peaks appear in the methanol blank, this confirms the specificity of the method.

3.8 Accuracy study of DRV Hcl And ACF

3.8.1 Accuracy Study of ACF by Simultaneous Equation method:

Table 10: Accuracy Study of ACF

Conc. (ug/ml)	**Absorbance**		**Conc. of ACF (ug/ml)**		**% Recovery**	
	234nm	**276 nm**	**234 nm**	**276 nm**	**234 nm**	**276 nm**
2	0.126	0.184	2.66	2.08	100.946	108.14
2	0.143	0.203	1.76	2.47	98.6391	104.9075
2	0.137	0.191	2.1	2.2	101.648	105.4517
4	0.197	0.269	4.1	4.37	98.9908	97.02972
4	0.221	0.296	3.41	4.33	95.98815	102.149

4	0.196	0.268	3.78	4.57	97.71361	102.69
6	0.326	0.425	6.3	5.77	101.016	101.5927
6	0.311	0.403	5.56	5.89	98.2545	102.042
6	0.310	0.410	5.92	5.88	97.1443	100.0251
				Mean	100.0530	100.9878
				SD	2.048253	3.76955
				% RSD	2.047167	3.732684

This table represents the accuracy validation data for Aceclofenac using absorbance at two wavelengths: 234 nm and 276 nm. From the above study, % RSD < 5% indicates acceptable precision and reproducibility. Mean recovery close to 100% confirms good accuracy of the method. The simultaneous equation method for aceclofenac shows excellent accuracy and reproducibility across a range of concentrations (2–6 µg/ml). % Recovery values fall within the acceptable range (98–102%), especially at 234 nm. %RSD values are within acceptable limits, confirming the method's reliability.

3.8.2 Accuracy study of Drv Hcl by simultaneous equation method:

Table 11: Accuracy Study of DRV Hcl

Conc. (ug/ml)	**Absorbance**		**Conc. of DRV HCL (ug/ml)**		**% Recovery**	
	234.0nm	**276.0 nm**	**234.0nm**	**276.0 nm**	**234.0nm**	**276.0nm**
2	0.266	0.121	1.95	2.07	99.17	102.75
2	0.291	0.136	1.96	2.005	98.48	100.25
2	0.57	0.117	1.94	1.95	97.10	97.75
4	0.477	0.212	4.06	4.05	101.58	101.37
4	0.444	0.188	4.07	4.005	101.92	100.12
4	0.453	0.185	4.03	3.95	100.89	98.87
6	0.680	0.285	5.99	6.005	99.86	100.08
6	0.684	0.285	5.97	6.05	99.63	100.91
6	0.632	0.260	6.005	6.005	100.09	100.08
				Mean	99.8577	100.2422
				SD	1.515204	1.421643
				%RSD	1.517362	1.418208

Highest concentration shows very tight recovery values, indicating strong linearity and minimal deviation. Mean recovery is very close to 100%, which suggests excellent accuracy. %RSD < 2% shows good precision and low variability[28,29]. The simultaneous equation method for drotaverine HCl shows high accuracy with recovery values mostly within the 98–102% acceptable range. The low %RSD (<2%) across all levels confirms the method is precise and reproducible.

3.9 Precision data:

3.9.1 Drotaverine Hcl:

Table 12: Precision data of Drotaverine

	Inter day					**Intra day**		
	Concentration	Mean	% RSD			Concentration	Mean	% RSD
234nm	2	0.262	1.2254		234nm	2	0.512	1.7255
	4	0.451	1.4753			4	0.195	1.4753
	6	0.682	0.2933			6	0.286	0.9003

	Concentration	Mean	% RSD		Concentration	Mean	% RSD
276nm	2	0.129	1.55	276nm	2	0.512	0.35
	4	0.185	1.622		4	0.268	1.341
	6	0.286	0.606		6	0.374	0.404

The % RSD values are all below 2%, indicating good inter-day precision. Intraday Precision (Measurements taken on the same day); All % RSD values are well below 2%, confirming excellent intraday precision. Particularly low % RSD at 276 nm for 2 µg/ml (0.35%) and 6 µg/ml (0.404%) reflects high reproducibility. Which conclude Precision is acceptable for all concentrations and wavelengths both inter-day and intraday. %RSD values are consistently below 2%, as per ICH guidelines, demonstrating that the method is reliable and reproducible. Lower %RSD at higher concentrations suggests better stability and consistency at those levels.

3.9.2 Aceclofenac:

Table 13: Precision data of Aceclofenac

	Inter day				**Intra day**		
	Concentration	Mean	% RSD		Concentration	Mean	% RSD
234nm	2	0.112	1.3679	234nm	2	0.512	1.72
	4	0.199	1.005		4	0.195	1.47
	6	0.29	1.7241		6	0.286	0.90
	Concentration	Mean	% RSD		Concentration	Mean	% RSD
276nm	2	0.175	1.435	276nm	2	0.512	0.35
	4	0.273	1.35		4	0.268 0.374	1.341 0.404
	6	0.381	1.972		6	0.512	0.35

Above study conclude the %RSD (Relative Standard Deviation) values for all concentrations are below 2%, indicating good precision both inter-day and intra-day. Lower %RSD values at 276 nm intra-day suggest better repeatability at this wavelength compared to 234 nm.[31] Consistency of mean values across both days and wavelengths supports method reliability.

3.10 LOD Parameter from data analysis:

Table 14: LOD data for DRV Hcl and Aceclofenac

Parameter	DRV Hcl(ug/ml		ACF(Ug/ml)	
	234.0nm	276.0nm	234.0nm	276.0nm
Residual SD	0.003608	0.000924	0.001336	0.001671

Slope	0.0734	0.028	0.0657	0.04331
SD of Y intercept	0.003495	0.00160	0.00362	0.002337

Table 15: Regression data

Wavelength(nm)	Residual SD of regression line		SD of Y intercept of Regression line	
	DRV Hcl (ug/ml)	ACF (ug/ml	DRV Hcl (ug/ml)	ACF (ug/ml)
234.0	0.162	0.067	1.57	0.181
276.0	0.1089	0.127	0.188	0.155

Limit of Detection (LOD) data and supporting regression parameters for Drotaverine HCl (DRV HCl) and Aceclofenac (ACF) at two wavelengths: 234 nm and 276 nm. At the 234 nm, DRV HCl shows better LOD using residual SD (0.162 µg/mL) than using intercept SD (1.57 µg/mL), showing that residual SD-based LOD is more sensitive. For ACF, 234 nm yields better sensitivity with residual SD (0.067 µg/mL). At 276 nm, DRV Hcl performs best overall with the lowest LOD (0.1089 µg/mL) based on residual SD.ACF shows a trade-off better residual-based LOD at 234 nm but better intercept-based LOD at 276 nm.DRV Hcl shows best detection sensitivity at 276 nm. ACF shows better detection at 234 nm using residual SD, but 276 nm performs slightly better in intercept-based estimation.

3.11 LOQ Parameter from data analysis:

Table 16: LOQ Data Analysis

Wavelength(nm)	Based on Residual SD of regression line		Based on SD of Y intercept of Regression line	
	DRV HCL (ug/ml)	ACF (ug/ml)	DRV HCL (ug/ml)	ACF (ug/ml)
234.0	0.491	0.203	4.76	0.550
276.0	0.33	0.387	0.571	0.519

DRV HCl: Better LOQ at 276 nm for both methods (especially using intercept SD: 0.571 vs. 4.76 at 234nm). Residual SD method is much more sensitive, showing lower LOQs compared to intercept-based.

ACF: Lower LOQ at 234 nm (0.203 µg/mL) using residual SD, which suggests better quantification sensitivity at this wavelength. The intercept based LOQs are slightly higher but still acceptable

3.12 Robustness Study:

3.12.1 Robustness of DRV Hcl

Table 17: Robustness data of DRV hcl

Sr. no	Concentration	Wavelength	Abs	Mean	SD	%RSD
1	2	234	0.965	0.9620	0.0026	0.0027
		235	0.960			
		232	0.961			
2	4	234	0.950	0.958	0.0072	0.007
		235	0.964			
		232	0.960			
3	6	234	0.961	0.964	0.0049	0.005
		235	0.970			
		232	0.962			

All %RSD values are below 2%, indicating excellent robustness. Small variations in wavelength do not significantly affect the absorbance values for DRV HCl [34,35] confirming the method's reliability under minor changes.

3.12.2 Robustness of ACF:

Table 18: Robustness data of Aceclofenac

Sr. no	Concentration	Wavelength	Abs	Mean	SD	%RSD
1	2	234	0.515	0.512	0.00264	0.0051
		235	0.510			
		232	0.511			
2	4	234	0.509	0.510	0.00152	0.0029
		235	0.513			
		232	0.510			
3	6	234	0.514	0.511	0.0020	0.00406
		235	0.510			
		232	0.511			

Again, all %RSD values are below 2%, indicating very good robustness. The absorbance remains stable even with small wavelength changes, so the method is robust for ACF as well. The robustness studies for both DRV HCl and ACF demonstrate that the developed analytical method is not sensitive to minor changes in wavelength, which is a critical validation parameter[22,37,38]. This ensures that the method will perform consistently under routine laboratory conditions.

3.13 Ruggedness Study

Table 19: Ruggedness study of DRV Hcl and ACF

Con.(ug/l)									
DRV Hcl	ACF	Change in analyst				Change in Instrument			
		DRV Hcl		ACF		DRV Hcl		ACF	
		234.0nm	276.0nm	234.0nm	276.0nm	234.0nm	276.0nm	234.0nm	276.0nm
8	10	0.786	0.348	0.419	0.685	0.898	0.335	0.418	0.698
8	10	0.78	0.349	0.411	0.684	0.802	0.352	0.498	0.677
8	10	0.78	0.351	0.411	0.689	0.798	0.341	0.455	0.694
8	10	0.78	0.341	0.415	0.685	0.847	0.348	0.467	0.678
8	10	0.78	0.347	0.444	0.681	0.830	0.339	0.473	0.688
8	10	0.78	0.349	0.409	0.6823	0.788	0.359	0.428	0.682
AVERAE		0.782	0.3473	0.41233	0.6823	0.8275	0.3459	0.4565	0.686
SD		0.002	0.0032	0.00388	0.00276	0.0411	0.0089	0.02967	0.008
%RSD		0.370	0.9403	0.94137	0.40286	4.96837	2.598	6.49942	1.258

Above table represents the ruggedness study of Drotaverine HCl (DRV HCl) and Aceclofenac (ACF), which is used to evaluate the reproducibility of results under different conditions, such as change in analyst and change in instrument.Conditions evaluated are **1. Change in Analyst 2. Change in Instrument**: Conclude that change in Analyst: %RSD < 2% for all conditions shows good ruggedness, meaning results are reproducible when different analysts perform the test. Change in Instrument: Some %RSD values exceed 2%, especially for DRV HCl at 234 nm (4.96%) and ACF at 234 nm (6.49%), indicating moderate variability.

3.14 Recovery study:

Table 20:

Sr. no	**Level**	**Conc Of Sample**	**Total conc**	**234.0nm**	**Conc found**	**SD**	**%Recovery**	**% RSD**
1	80 %	6	10.8	0.632	10.902	0.18	100.94	1.627
2	100%	6	12	0.733	12.198	0.16	101.64	1.345
3	120%	6	13.2	0.847	13.02	0.5	98.639	3.845
4	80 %	8	14.4	0.958	14.111	0.1	97.990	0.678
5	100%	8	16	1.185	16.02	0.4	100.14	2.512
6	120%	8	17.6	1.262	17.102	0.49	97.173	2.886
7	80 %	10	18	1.371	18.183	0.59	101.01	3.234
8	100%	10	20	1.520	19.651	0.04	98.254	0.226
9	120%	10	22	1.695	21.372	0.069	97.144	0.218

%Recovery Data of Drotaverine at 234.0nm

Sr. no	**Level**	**Conc Of Sample**	**Total conc**	**276.0nm**	**Conc found**	**SD**	**%Recovery**	**% RSD**
1	80 %	6	10.8	0.232	10.788	0.068	99.89	0.626
2	100%	6	12	0.317	12.298	0.139	102.5	1.127
3	120%	6	13.2	0.377	13.368	0.214	101.3	1.603
4	80 %	8	14.4	0.410	13.957	0.045	96.92	0.322
5	100%	8	16	0.541	16.3	0.593	101.9	3.637
6	120%	8	17.6	0.595	17.263	0.088	98.09	0.51
7	80 %	10	18	0.638	18.03	0.227	100.2	1.261
8	100%	10	20	0.742	19.873	0.036	99.37	0.18
9	120%	10	22	0.232	21.497	0.064	97.71	0.299

Table 21: % Recovery Data of Drotaverine at 276.0 nm

The result at 276.0nm shows a recovery study for drotaverine, but at 234.0nm. The %recovery ranges from 97.144% to 101.64% again, acceptable. % RSD mostly <3.5%, indicating good precision.

Sr. no	**Level**	**Conc Of Sample**	**Total conc**	**276.0nm**	**Conc found**	**SD**	**%Recovery**	**% RSD**
1	80 %	6	10.8	0.62	11.679	0.1582	108.14	1.355
2	100%	6	12	0.711	12.588	0.01	104.90	0.079
3	120%	6	13.2	0.778	13.259	0.1709	100.45	1.289
4	80 %	8	14.4	0.864	14.116	0.426	98.02	3.018
5	100%	8	16	0.989	15.358	0.0264	95.98	0.172
6	120%	8	17.6	1.174	17.197	0.9375	97.71	5.451
7	80 %	10	18	1.283	18.286	0.0981	101.59	0.536
8	100%	10	20	1.496	20.408	0.0359	102.04	0.176
9	120%	10	22	1.656	22.005	0.709	100.02	3.222

Table 22: % Recovery Data of Aceclofenac At 234.0 nm

Sr. no	**Level**	**Conc Of Sample**	**Total conc**	**234.0nm**	**Conc found**	**SD**	**%Recovery**	**% RSD**
1	80 %	6	10.8	0.516	10.88	0.326	100.946	3
2	100%	6	12	0.613	11.79	0.293	101.648	2.49
3	120%	6	13.2	0.714	12.8	0.224	98.6391	1.75
4	80 %	8	14.4	0.821	13.86	0.264	97.9908	1.91
5	100%	8	16	0.961	15.26	0.443	102.149	2.91
6	120%	8	17.6	1.101	16.66	0.623	97.1731	3.74
7	80 %	10	18	1.136	17.01	0.782	101.016	4.6
8	100%	10	20	1.337	19.01	0.453	98.2545	2.38
9	120%	10	22	1.506	20.91	0.347	97.1443	1.66

Table 23: % Recovery Data of Aceclofenac At 276.0 nm

As above % Recovery of Aceclofenac at 234.0 nm recovery range: ~97.14% to 102.15% RSD: mostly under 3%, with one slightly above 4.6%, still within acceptable limits for pharmaceutical analysis.Conclusion is that the method is accurate and precise at this wavelength for Aceclofenac. %recovery of Aceclofenac at 276.0 nm. Recovery range ~95.98% to 108.14% (a bit high at the low concerned. Recovery Range: ~95.98% to 108.14%(acceptable). Precision (% RSD) is within acceptable limits (< 5% Both Drotaverine and Aceclofenac show good recovery across the tested concentration ranges.

4. CONCLUSION:

A simple and efficient stability indicating UV Spectro photometric method was developed and validated for simultaneous estimation of Drotaverine HCL and Aceclofenac in bulk drug and pharmaceutical formulation. The method found to be precise, accurate, linear, robust and rugged during validation. Satisfactory results were obtained from the validation of them. The purity of both analytes were unaffected by the presence of degradation products and thus confirms the stability indicating power of developed method. The method was validated as per ICH guidelines, demonstrating excellent linearity in the concentration range of 4–20 µg/mL for both drugs. The percentage recovery for Drotaverine HCl and Aceclofenac ranged from 98% to 102%, confirming the accuracy of the method. The low standard deviation and %RSD values further indicate the precision and reliability of the results. Therefore, the proposed method can be successfully applied for routine quality control analysis of Drotaverine HCl and Aceclofenac in combined pharmaceutical formulations.

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