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Research

METHOD DEVELOPMENT AND VALIDATION FOR THE DETERMINATION OF AMLODIPINE AND ENALAPRIL MALEATE IN ACTIVE PHARMACEUTICAL INGREDIENT AND COMBINED TABLET DOSAGE FORM BY RP-HPLC

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	Abstract
Published on:	A rapid and precise reverse phase high performance liquid chromatographic method has been developed for the validated of Amlodipine and Enalapril maleate, in its pure form as well as in tablet dosage form. Chromatography was carried out on a Altima C18 (4.6 x 150mm, 5µm) column using a mixture of Methanol: TEA Buffer pH 4.5: Acetonitrile (50:25:25) as the mobile phase at a flow rate of 1.0ml/min, the detection was carried out at 225 nm. The retention time of the Amlodipine and Enalapril maleate was 2.102, 3.537 ±0.02min respectively. The method produce linear responses in the concentration range of 5-25mg/ml of Amlodipine and 12.5-62.5mg/ml of Enalapril maleate. The method precision for the determination of assay was below 2.0%RSD. The method is useful in the quality control of bulk and pharmaceutical formulations.
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	Keywords: Amlodipine, Enalapril maleate, RP-HPLC, validation.

INTRODUCTION

1. Introduction to HPLC^[1-28]

In the modern pharmaceutical industry, high-performance liquid chromatography (HPLC) is the major and integral analytical tool applied in all stages of drug discovery, development and production. It is ideal for the analysis of many drugs in both dosage forms and biological fluids due to its simplicity, high specificity and good sensitivity.

High Performance Liquid Chromatography (HPLC) is a technique that has arisen from the application to liquid chromatography the use of an instrumentation that was originally developed for gas chromatography. High Pressure Liquid Chromatography was developed in the mid-1970 and was improved with the development of column packing material and the additional convenience of on-line detectors. The various components of HPLC are pumps (solvent delivery system), mixing unit, gradient controller and solvent degasser, injector (manual or automatic), guard column, analytical columns, detectors, recorders and/or integrators. Recent models are equipped with computers and software for data acquisition and processing. The mobile phase in HPLC refers to the solvent being continuously applied to the column or stationary phase at a flow rate of 1-5 cm³/min. The mobile phase acts as a carrier for the sample solution. The chemical interactions of the mobile phase and sample with the column determine the degree of migration and separation of components contained in the sample. The mobile phase can be altered in order to manipulate the interactions of the sample and the stationary phase.

1.1.1 Types of Chromatography^[1]

1. Normal-phase chromatography

Mechanism: Retention by interaction with the polar surface of the stationary phase with polar parts of the sample molecules.

Stationary phase: SiO₂, Al₂O₃, -NH₂, -CN, -Diol, -NO₂, etc.

Mobile phase: Heptane, hexane, cyclohexane, CHCl₃, CH₂Cl₂, dioxane, methanol, etc.

Application: Separation of non-ionic, non-polar to medium polar substances. Disadvantage: Lack of reproducibility of retention times as water or protic organic solvents change the hydration state of the silica or alumina chromatographic media.

2. Reversed-phase chromatography

Mechanism: Retention by interaction of the stationary phase's non-polar hydrocarbon chain with non-polar parts of the sample molecules.

Stationary phase: n-octadecyl (RP-18), n-octyl (RP-8), ethyl (RP-2), phenyl, (CH₂)_n-CN, (CH₂)_n-diol, etc.

Mobile phase: Methanol, acetonitrile, water, buffer (sometimes with additives of THF or Dioxane), etc.

Application: Separation of non-ionic and ion forming non-polar to medium polar substances (carboxylic acids, hydrocarbons). If ion forming substances (as carboxylic acids) are to be separated, a pH control by buffers is necessary.

3. Reversed-phase ion-pair chromatography

Mechanism: Ionic sample molecules are ionically bound to an ion-pair reagent. The ion-pair reagent contains an unpolar part suitable for interaction with the unpolar hydrocarbon chain of the stationary phase.

Stationary phase: Reversed phase materials (RP-18, RP-8, CN), etc.

Mobile phase: Methanol, acetonitrile, buffer with added ion-pair reagent in the concentration range of 0.001 to 0.01 M, etc.

Application: Ionic substances often show very poor retention in reversed phase chromatography. To overcome this difficulty an ion-pair reagent is added to the eluent.

4. Ion-exchange chromatography

Mechanism: Retention of reversible ionic bonds on charged groups of the stationary phase

Stationary phase:

	Strong	Weak
Cation exchanger	SO_3^-	COO^-
Anion exchanger	NR_3^+	NHR_2^+

Mobile phase: Aqueous buffer systems.

Application: Separation of substances which can form ions such as inorganic ions, organic acids, organic bases, proteins, nucleic acids.

1.1.2 Advantages of HPLC^[2]

- 1) It provides specific, sensitive and precise method for analysis of the different complicated sample.
- 2) There is ease of sample preparation and sample introduction.
- 3) There is speed of analysis.
- 4) The analysis by HPLC is specific, accurate and precise.
- 5) It offers advantage over gas chromatography in analysis of many polar, ionic substances, high molecular weight substances, metabolic products and thermolabile as well as nonvolatile substances.

1.1.3 Applications of HPLC^[2]

- a) Natural Products: HPLC is an ideal method for the estimation of various components in plant extracts which resemble in structure and thus demand a specific and very sensitive method e.g., analysis of digitalis, cinchona, liquorice, and ergot extracts.
- b) Stability studies: HPLC is now used for ascertaining the stability of various pharmaceuticals. With HPLC the analysis of the various degradation products can be done and thus stability indicating HPLC systems have been developed.
- c) Bioassays and its complementation: Complex molecules as antibiotics and peptide hormones are mainly analysed by bioassay which suffer from high cost, necessity replicates, poor precision and length of time required. Also bioassay gives an overall estimate of potency and gives no guidance about the composition. Thus HPLC can be used to complement bioassays and give an activity profile. It has been used for analysis of chloramphenicol, penicillins, clotrimoxazole, sulfas and peptides hormones.
- d) HPLC has also been used in the cosmetic industry for quality control of various cosmetics.

EXPERIMENTAL WORK

INSTRUMENTS USED

HPLC WATERS Alliance 2695 separation module, software: Empower 2, 996 PDA detector.

pH meter	Lab India
Weighing machine	Sartorius
Volumetric flasks	Borosil

Pipettes and Burettes Borosil

CHEMICALS USED:

Amlodipine Sura labs
 Enalapril maleate Sura labs
 Water and Methanol for HPLC LICHROSOLV (MERCK)
 Acetonitrile for HPLC Merck

RESULTS AND DISCUSSION

Optimised Chromatogram (Standard)

Mobile phase : Methanol: TEA Buffer pH 4.5: Acetonitrile (50:25:25)

Column : Altima C18 (4.6×150mm, 5.0 µm)

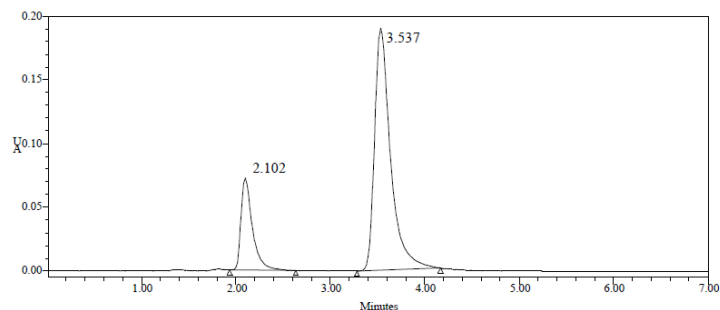
Flow rate : 1 ml/min

Wavelength : 350 nm

Column temp : 40°C

Injection Volume : 10 µl

Run time : 7 minutes



Optimized Chromatogram
Table: - peak results for optimised

S. No	Peak name	R _t	Area	Height	USP Resolution	USP Tailing	USP plate count
1	Amlodipine	2.102	607323	72100		0.96	5586.0
2	Enalapril maleate	3.537	2231111	190007	2.97	1.22	5371.0

Observation: From the above chromatogram it was observed that the Amlodipine and Enalapril maleate peaks are well separated and they shows proper retention time, resolution, peak tail and plate count. So it's optimised trial.

Optimised Chromatogram (Sample)

Mobile phase : Methanol: TEA Buffer pH 4.5: Acetonitrile (50:25:25)

Column : Altima C18 (4.6×150mm, 5.0 µm)

Flow rate : 1 ml/min

Wavelength : 350 nm

Column temp : 40°C

Injection Volume : 10 µl

Run time : 7 minutes

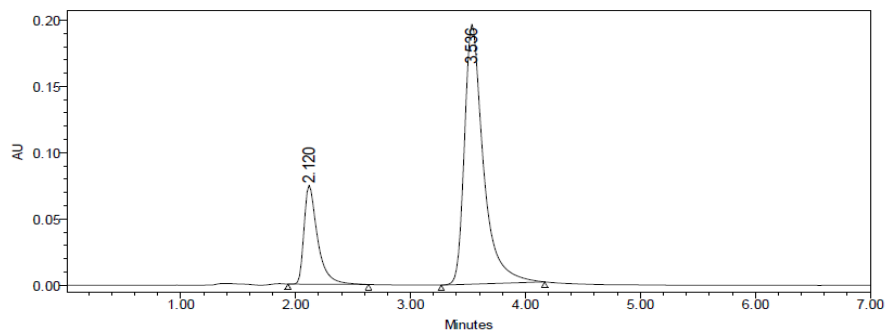


Figure: Optimised Chromatogram (Sample)

Table: Optimised Chromatogram (Sample)

S. No	Peak name	R _t	Area	Height	USP Resolution	USP Tailing	USP plate count
1	Amlodipine	2.120	775610	130275		0.98	6253
2	Enalapril maleate	3.536	555592	93740	5.06	1.23	7836

Acceptance criteria:

- Resolution between two drugs must be not less than 2
- Theoretical plates must be not less than 2000
- Tailing factor must be not less than 0.9 and not more than 2.
- It was found from above data that all the system suitability parameters for developed method were within the limit.

VALIDATION

Blank:

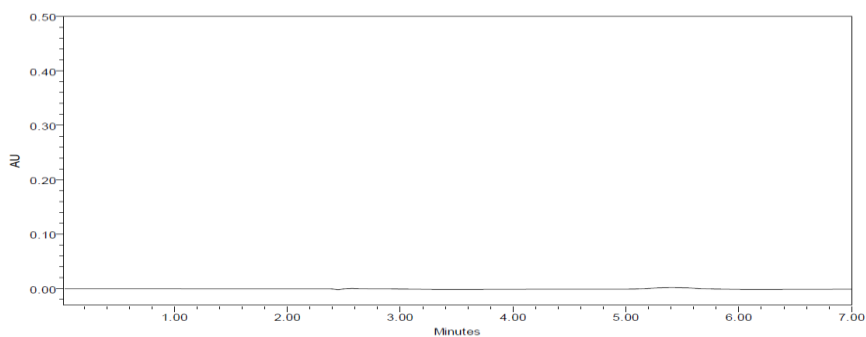


Fig: Chromatogram showing blank (mobile phase preparation)

System suitability:

Table: Results of system suitability for Amlodipine

S.No	Name	Rt	Area	Height	USP plate count	USP Tailing
1	Amlodipine	2.117	608452	71498	5643	1.9
2	Amlodipine	2.118	606820	126412	5432	1.6
3	Amlodipine	2.116	608452	126471	5123	1.6
4	Amlodipine	2.109	595267	129859	5207	1.7
5	Amlodipine	2.102	596608	124691	5481	1.6
Mean			603119.8			
Std. Dev			6607.31			
% RSD			1.09			

Acceptance criteria:

- %RSD of five different sample solutions should not more than 2
- The %RSD obtained is within the limit, hence the method is suitable

Table: Results of system suitability for Enalapril maleate

Sno	Name	Rt	Area	Height	USP plate count	USP Tailing	USP Resolution
1	Enalapril maleate	3.547	2234724	188631	5043	1.2	2.07
2	Enalapril maleate	3.539	2240080	2614821	5432	1.4	2.05
3	Enalapril maleate	3.547	2234724	2321451	5987	1.5	2.0
4	Enalapril maleate	3.565	2204466	2324710	5845	1.6	2.01
5	Enalapril maleate	3.537	2209574	2531247	5371	1.6	2.01
Mean			2224714				
Std. Dev			16399.05				
% RSD			0.73				

Acceptance criteria:

- %RSD for sample should be NMT 2
- The %RSD for the standard solution is below 1, which is within the limits hence method is precise.

SPECIFICITY

The ICH documents define specificity as the ability to assess unequivocally the analyte in the presence of components that may be expected to be present, such as impurities, degradation products, and matrix components.

Analytical method was tested for specificity to measure accurately quantitate Amlodipine and Enalapril maleate in drug product.

Assay (Standard):

Table: Peak results for assay standard

Sno	Name	Rt	Area	Height	USP Resolution	USP Tailing	USP plate count	Injection
1	Amlodipine	2.102	607323	128898		1.7	2586	1
2	Enalapril maleate	3.537	558777	2231111	2.04	1.6	2371	1
3	Amlodipine	2.105	606379	127950		1.7	2636	2
4	Enalapril maleate	3.552	578377	2220237	2.00	1.6	2414	2
5	Amlodipine	2.112	606885	129769		1.7	2561	3
6	Enalapril maleate	3.560	556966	2217353	2.04	1.6	2384	3

Assay (Sample):

Fig: Chromatogram showing assay of sample injection-3

Table: Peak results for Assay sample

Sno	Name	Rt	Area	Height	USP Resolution	USP Tailing	USP plate count	Injection
1	Amlodipine	2.120	775610	130275		0.98	7253	1
2	Enalapril maleate	3.536	555592	93740	2.06	1.23	8836	1
3	Amlodipine	2.120	689956	73869		1.05	6530	2
4	Enalapril maleate	3.537	575685	129125	2.04	0.99	7270	2
5	Amlodipine	2.102	607323	128898		1.7	7586	3
6	Enalapril maleate	3.537	558777	2231111	2.04	1.6	8371	3

%ASSAY =

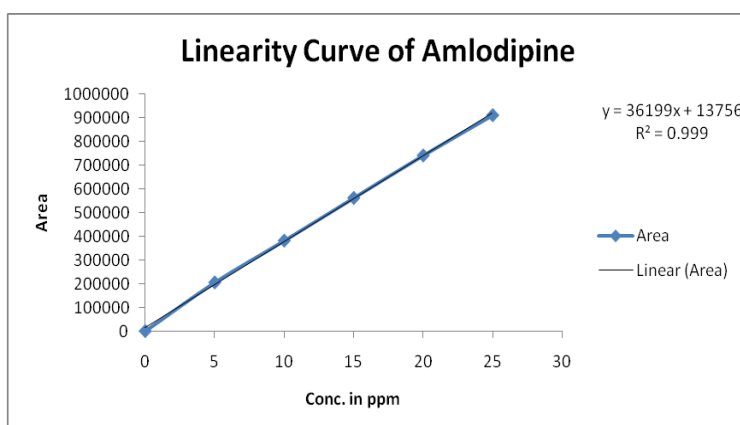
$$\frac{\text{Sample area}}{\text{Standard area}} \times \frac{\text{Weight of standard}}{\text{Dilution of standard}} \times \frac{\text{Dilution of sample}}{\text{Weight of sample}} \times \frac{\text{Purity}}{100} \times \frac{\text{Weight of tablet}}{\text{Label claim}} \times 100$$

The % purity of Amlodipine and Enalapril maleate in pharmaceutical dosage form was found to be 99.6%.

LINEARITY

CHROMATOGRAPHIC DATA FOR LINEARITY STUDY:**Amlodipine:**

Concentration Level (%)	Concentration $\mu\text{g/ml}$	Average Peak Area
33.3	5	205035
66.6	10	381239
100	15	561128
133.3	20	740162
166.6	25	909922

**Figure 6.3.4 Calibration graph for Amlodipine****LINEARITY PLOT:**

The plot of Concentration (x) versus the Average Peak Area (y) data of Amlodipine is a straight line.

$$Y = mx + c$$

$$\text{Slope (m)} = 36199$$

$$\text{Intercept (c)} = 13756$$

$$\text{Correlation Coefficient (r)} = 0.999$$

VALIDATION CRITERIA: The response linearity is verified if the Correlation Coefficient is 0.99 or greater.

CONCLUSION: Correlation Coefficient (r) is 0.99, and the intercept is 13756. These values meet the validation criteria.

Enalapril maleate

Concentration Level (%)	Concentration $\mu\text{g/ml}$	Average Peak Area
33	12.5	757881
66	12.5	757881
100	25	1458941
133	37.5	2132457
166	50	2901811

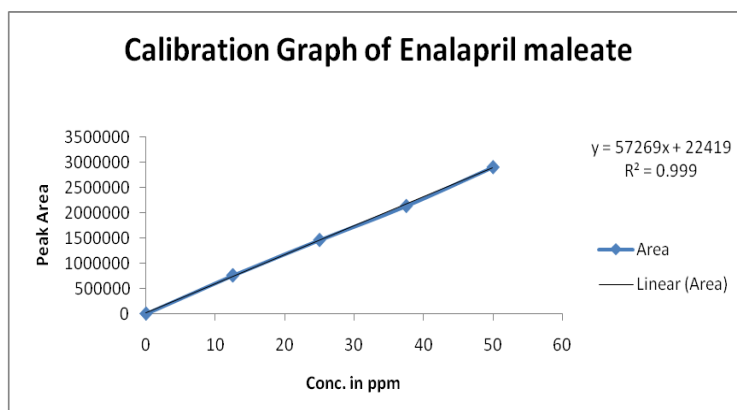


Figure 6.3.4 calibration graph for Enalapril maleate

LINEARITY PLOT:

The plot of Concentration (x) versus the Average Peak Area (y) data of Enalapril maleate is a straight line.

$$Y = mx + c$$

$$\text{Slope (m)} = 56304$$

$$\text{Intercept (c)} = 33265$$

$$\text{Correlation Coefficient (r)} = 0.999$$

VALIDATION CRITERIA: The response linearity is verified if the Correlation Coefficient is 0.99 or greater.

CONCLUSION: Correlation Coefficient (r) is 0.99, and the intercept is 33265. These values meet the validation criteria.

Precision:

The precision of an analytical procedure expresses the closeness of agreement (degree of scatter) between a series of measurements obtained from multiple sampling of the same homogeneous sample under the prescribed conditions.

REPEATABILITY

Obtained Five (5) replicates of 100% accuracy solution as per experimental conditions. Recorded the peak areas and calculated % RSD.

Table: Results of repeatability for Amlodipine:

Sno	Name	Rt	Area	Height	USP plate count	USP Tailing
1	Amlodipine	2.108	602223	128898	2586	1.6
2	Amlodipine	2.105	607748	129233	2947	1.4
3	Amlodipine	2.113	607302	127409	2468	1.6
4	Amlodipine	2.109	608674	127047	2146	1.9
5	Amlodipine	2.109	607376	129859	2307	1.7
Mean			606665			
Std. Dev			2542.3			
% RSD			0.42			

Acceptance criteria:

- %RSD for sample should be NMT 2
- The %RSD for the standard solution is below 1, which is within the limits hence method is precise.

Table: Results of method precession for Enalapril maleate:

Sno	Name	Rt	Area	Height	USP plate count	USP Tailing
1	Enalapril maleate	3.552	2220333	2231111	1.6	2371
2	Enalapril maleate	3.550	2221573	2674210	1.6	2841
3	Enalapril maleate	3.564	2215483	2231261	1.5	2816
4	Enalapril maleate	3.564	2217379	2421301	1.5	2872
5	Enalapril maleate	3.565	2211255	2324710	1.6	2845
Mean			2217205		1.6	2841
Std. Dev			4100.8			
% RSD			0.18			

Acceptance criteria:

- %RSD for sample should be NMT 2
- The %RSD for the standard solution is below 1, which is within the limits hence method is precise.

Intermediate precision:**Day 1:****Table: Results of Intermediate precision for Amlodipine**

Sno	Name	Rt	Area	Height	USP plate count	USP Tailing
1	Amlodipine	2.108	596608	128898	2547	1.6
2	Amlodipine	2.105	598959	129233	2944	1.4
3	Amlodipine	2.113	595728	127409	2361	1.6
4	Amlodipine	2.109	594485	127047	2546	1.9
5	Amlodipine	2.109	595267	129859	2207	1.7
6	Amlodipine	2.102	596608	124691	2481	1.6
Mean			596209			
Std. Dev			1718.7			
% RSD			0.29			

Acceptance criteria:

- %RSD of Six different sample solutions should not more than 2

Table: Results of Intermediate precision for Enalapril maleate

Sno	Name	Rt	Area	Height	USP plate count	USP Tailing	USP Resolution
1	Enalapril maleate	3.552	2207732	2231134	8371	1.5	2.04
2	Enalapril maleate	3.550	2202266	2674210	6841	1.6	2.03
3	Enalapril maleate	3.564	2209375	2247461	7816	1.6	2.01
4	Enalapril maleate	3.564	2204037	2454301	8872	1.6	2.05
5	Enalapril maleate	3.565	2204466	2324710	4845	1.6	2.02
6	Enalapril maleate	3.537	2209574	2531247	8371	1.6	2.03
Mean			2205575				
Std. Dev			2899.8				
% RSD			0.13				

Acceptance criteria:

- %RSD of Six different sample solutions should not more than 2
- The %RSD obtained is within the limit, hence the method is rugged.

Day 2:**Table: Results of Intermediate precision Day 2 for Amlodipine**

Sno	Name	Rt	Area	Height	USP plate count	USP Tailing
1	Amlodipine	2.102	602155	127998	5586	1.5
2	Amlodipine	2.105	603662	134844	5636	1.6
3	Amlodipine	2.112	603931	161103	5432	1.6
4	Amlodipine	2.113	607302	127409	5468	1.6
5	Amlodipine	2.109	608674	127047	5146	1.9
6	Amlodipine	2.109	607376	129859	5307	1.7
Mean			605516.7			
Std. Dev			2602.622			
% RSD			0.42			

Acceptance criteria:

- %RSD of Six different sample solutions should not more than 2

Table: Results of Intermediate precision for Enalapril maleate

Sno	Name	Rt	Area	Height	USP plate count	USP Tailing	USP Resolution
1	Enalapril maleate	3.537	2241579	2263528	2371	1.6	7.98
2	Enalapril maleate	3.552	2236409	2224418	2414	1.6	6.4
3	Enalapril maleate	3.560	2239093	2233725	2384	1.6	8.9
4	Enalapril maleate	3.564	2215483	2231261	2816	1.5	8.3
5	Enalapril maleate	3.564	2217379	2421301	2872	1.5	7.5
6	Enalapril maleate	3.565	2211255	2324710	2845	1.6	5.3
Mean			2226866				
Std. Dev			13567.02				
% RSD			0.60				

Acceptance criteria:

- %RSD of Six different sample solutions should not more than 2
- The %RSD obtained is within the limit, hence the method is rugged.

Accuracy

Accuracy at different concentrations (50%, 100%, and 150%) were prepared and the % recovery was calculated.

The accuracy results for Amlodipine

%Concentration (at specification Level)	Area	Amount Added (ppm)	Amount Found (ppm)	% Recovery	Mean Recovery
50%	287774	7.5	7.56	100.8	99.6%
100%	551495	15	14.8	98.6	
150%	825175	22.5	22.4	99.5	

The accuracy results for Enalapril maleate

%Concentration (at specification Level)	Area	Amount Added (ppm)	Amount Found (ppm)	% Recovery	Mean Recovery
50%	1104782	18.75	18.73	100%	100%
100%	2105321	37.5	37.4	99.9%	
150%	3211306	56.25	56.21	100%	

Acceptance Criteria:

- The percentage recovery was found to be within the limit (98-102%).

The results obtained for recovery at 50%, 100%, 150% are within the limits. Hence method is accurate.

LIMIT OF DETECTION

The detection limit 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.

$$\text{LOD} = 3.3 \times \sigma / s$$

Where

σ = Standard deviation of the response

S = Slope of the calibration curve

Result:

Amlodipine :

$$= 3.3 \times 3188.4/36199$$

$$= 0.2 \mu\text{g/ml}$$

Enalapril maleate:

$$= 3.3 \times 39656.07/56304$$

$$= 2.3 \mu\text{g/ml}$$

LIMIT OF QUANTITATION

The quantitation limit of an individual analytical procedure is the lowest amount of analyte in a sample which can be quantitatively determined.

$$\text{LOQ} = 10 \times \sigma / S$$

Where

σ = Standard deviation of the response

S = Slope of the calibration curve

Result:

Amlodipine :

$$= 10 \times 3188.481242/36199$$

$$= 0.8 \mu\text{g/ml}$$

Enalapril maleate:

$$= 10 \times 39656.07/56304$$

$$= 7.04 \mu\text{g/ml}$$

Robustness

Table: Results for Robustness

Amlodipine:

Parameter used for sample analysis	Peak Area	Retention Time	Theoretical plates	Tailing factor
Actual Flow rate of 1.0 mL/min	607323	2.102	5586	1.7
Less Flow rate of 0.9 mL/min	674735	2.330	5231	1.7

More Flow rate of 1.1 mL/min	1408920	1.950	5234	1.7
Less organic phase	606093	2.290	5643	1.4
More organic phase	603559	1.998	5298	1.5

Acceptance criteria:

The tailing factor should be less than 2.0 and the number of theoretical plates (N) should be more than 2000.

Enalapril maleate:

Parameter used for sample analysis	Peak Area	Retention Time	Theoretical plates	Tailing factor
Actual Flow rate of 1.0 mL/min	558777	3.537	5371	1.6
Less Flow rate of 0.9 mL/min	2505636	3.885	5324	1.7
More Flow rate of 1.1 mL/min	1408920	3.263	5098	1.7
Less organic phase	2239255	4.435	5239	1.2
More organic phase	2300346	3.009	5647	1.0

Acceptance criteria:

The tailing factor should be less than 2.0 and the number of theoretical plates (N) should be more than 2000.

SUMMARY

The analytical method was developed by studying different parameters.

First of all, maximum absorbance was found to be at 350 nm and the peak purity was excellent.

Injection volume was selected to be 10µl which gave a good peak area.

The column used for study was Altima C₁₈ because it was giving good peak.

Ambient temperature was found to be suitable for the nature of drug solution. The flow rate was fixed at 1.0ml/min because of good peak area and satisfactory retention time.

Mobile phase is Methanol: TEA Buffer pH 4.5: Acetonitrile (50:25:25) was fixed due to good symmetrical peak. So this mobile phase was used for the proposed study.

Run time was selected to be 7 min because analyze gave peak around 2.102, 3.537 ±0.02min respectively and also to reduce the total run time.

The percent recovery was found to be 98.0-102 was linear and precise over the same range. Both system and method precision was found to be accurate and well within range.

The analytical method was found linearity over the range 5-25mg/ml of Amlodipine and 12.5-62.5mg/ml of Enalapril maleate of the target concentration.

The analytical passed both robustness and ruggedness tests. On both cases, relative standard deviation was well satisfactory.

CONCLUSION

In the present investigation, a simple, sensitive, precise and accurate RP-HPLC method was developed for the quantitative estimation of Amlodipine and Enalapril maleate in bulk drug and pharmaceutical dosage forms.

This method was simple, since diluted samples are directly used without any preliminary chemical derivatisation or purification steps.

Amlodipine and Enalapril maleate was freely soluble in ethanol, methanol and sparingly soluble in water.

Methanol: TEA Buffer pH 4.5: Acetonitrile (50:25:25) was chosen as the mobile phase. The solvent system used in this method was economical.

The % RSD values were within 2 and the method was found to be precise.

The results expressed in Tables for RP-HPLC method was promising. The RP-HPLC method is more sensitive, accurate and precise compared to the Spectrophotometric methods.

This method can be used for the routine determination of Amlodipine and Enalapril maleate in bulk drug and in Pharmaceutical dosage forms.

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