PHARMACIA

Pharmacia 68(4): 811–818
DOI 10.3897/pharmacia.68.e72991

Research Article

Spectrophotometric methods for the determination of lisinopril in medicines

Nataliia Shulyak[1,2], Kateryna Budzivula[1], Tetyana Kucher[1], Liubomyr Kryskiw[1], Olha Poliak[1], Liliya Logoyda[1]

1 *Department of Pharmaceutical Chemistry, I. Horbachevsky Ternopil National Medical University, Ternopil, Ukraine*
2 *Municipal Institution of Higher Education "Volyn Medical Institute" of the Volyn Oblast Counsil, Lutsk, Ukraine*

Corresponding author: Liliya Logoyda (logojda@tdmu.edu.ua)

Received 13 August 2021 ♦ **Accepted** 14 September 2021 ♦ **Published** 18 October 2021

Citation: Shulyak N, Budzivula K, Kucher T, Kryskiw L, Poliak O, Logoyda L (2021) Spectrophotometric methods for the determination of lisinopril in medicines. Pharmacia 68(4): 811–818. https://doi.org/10.3897/pharmacia.68.e72991

Abstract

Two simple, rapid and green spectrophotometric methods are described for the determination of lisinopril medicines. The determination is based on the reaction of the primary amino group of the lisinopril with ninhydrin in aqueous medium (Method I) and reaction on the carboxylic group of the lisinopril with copper (II) sulfate (Method II). For both methods, optimal spectrophotometric conditions were established. The linear relationship was found between absorbance at λmax and concentration of drug in the range 40–60 μg/mL (Method I) and 0.592–2.072 mg/mL (Method II). Regression analysis of Beer's law plot at 400 nm yielded the regression equation, y = 7.4929x – 0.0545 (Method I) and at 730 nm y = 0.0443x – 0.0832 (Method II). High values of correlations coefficient (R^2 = 0.9917 (Method I) and R^2 = 0.999 (Method II)) and small values of intercept validated the linearity of calibration curve and obedience to Beer's law. The LOD and LOQ values were calculated to be 6.91 μg/mL and 23.01 μg/mL respectively (Method I) and 0.11 mg/mL and 0.36 mg/mL respectively (Method II). Intra-day and inter-day accuracy and precision were in acceptable limits. The proposed methods were applied for the quantification of lisinopril in tablets pertaining to three commercial formulations. Analytical eco-scale for greenness assessment of the proposed spectrophotometric methods showed that both methods correspond to excellent green analysis.

Keywords

Analytical Eco-Scale, Copper (II) sulfate, Lisinopril, Ninhydrin, Spectrophotometry

Introduction

Nowadays, hypertension is becoming a worldwide problem. Several medicines used for treatment hypertension. Lisinopril is a competitive inhibitor of angiotensin-converting enzyme (ACE) and prevents the conversion of angiotensin I to angiotensin II, which is a potent vasoconstrictor (https://www.ncbi.nlm.nih.gov/books/NBK482230/).The chemical name of lisinopril is (2*S*)-1-[(2*S*)-6-amino-2-[[(1*S*)-1-carboxy-3-phenylpropyl]amino]hexanoyl]pyrrolidine-2-carboxylic acid (Fig. 1) (European Pharmacopoeia 2020). Physico-chemical methods of analysis are increasingly being introduced into basic pharmaceutical research and the practice of pharmaceutical analysis, given their high sensitivity, accuracy, specificity and expressiveness. Chemists-analysts constantly work on the development of new methods for the analysis of API in drugs and biological fluids and on their optimization in order to save time and materials, which also ensures the effectiveness of the developed methodology. European Pharmacopoeia 2020 has a monograph on the substance of

lisinopril dihydrate. Identification of lisinopril dihydrate EPh regulates to perform the absorption spectrophotometry in the infrared region and specific optical rotation and the quantitative determination – alkalimetry.

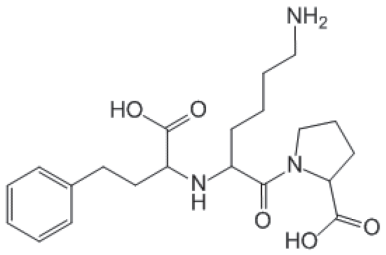


Figure 1. Chemical structure of lisinopril.

Analytical methods of analysis such as HPLC (El Gindy et al. 2001; Beasley et al. 2005; Ivanovic et al. 2007; Chauhan et al. 2011; Sultana et al. 2011; Naveed et al. 2012; Arayne et al. 2013; Peleshok et al. 2021a; Shulyak et al. 2021), LC/MS (Andreas et al. 2003; Huang et al. 2006; Drapak et al. 2019a, b), gas chromatography with mass detection (Leis et al. 1998, 1999), spectrophotometry (El-Emam et al. 2004; Rahman et al. 2005a, b; Basavaiah et al. 2009; Jamakhandi et al. 2011; Sbârcea et al. 2014) have been developed for the determination of lisinopril in medicines and biological liquids. Spectrophotometry as a quantitative analytical methodology belongs to the foremost oft-used analytical techniques in pharmaceutical analysis. It provides sensible and significant economic benefits over alternative ways. Visible spectrophotometry is the technique of choice even today because of its inherent simplicity, selectivity, sensitivity, precision, accuracy and cost-effectiveness. In the available sourses, several different spectrophotometric methods have been reported for quantification of lisinopril in medicines using different reagents (El Gindy et al. 2001; El-Emam et al. 2004; Rahman et al. 2005a, b; Basavaiah et al. 2009; Jamakhandi et al. 2011; Sbârcea et al. 2014). However, many of these methods are limited in their applications or rather much tedious and time consuming. There is, therefore, a need for a rapid simple green spectrophotometric methods for the assay of lisinopril in medicinal products.

The present paper describes a rapid, simple and green visible spectrophotometric methods for the determination of lisinopril in medicines. The determination is based on the reaction of the primary amino group of the lisinopril with ninhydrin in aqueous medium (Method I) and reaction on the carboxylic group of the lisinopril with copper (II) sulfate (Method II).

Aim of work

We aimed to develop and validate rapid, simple and green visible spectrophotometric methods for the determination of lisinopril in medicines.

Materials and methods

Apparatus

A double – beam Shimadzu UV-Visible spectrophotometer, with spectral bandwidth of 1 nm wavelength accuracy ±0.5 nm, Model –UV 1800 (Japan), Software UV-Probe 2.62, and a pair of 1 cm matched quartz cells, was used to measure absorbance of the resulting solution. Designed in accordance with the governing Japanese and European Pharmacopoeia, the new UV-1800 UV-VIS spectrophotometer achieves a resolution of 1 nm, the highest in its class, in a compact design.

Reagents and standards

All the chemicals were used of analytical reagent grade.

0.2% solution of ninhydrin

200 mg of chemical (Sigma-Aldrich) were dissolved in water and brought to 100 mL with water. Freshly prepared ninhydrin solution was always used.

0.02 M Copper (II) sulfate

The solution was prepared by dissolving 319 mg of chemical (Honeywell Fluka) in water and diluting to 100 mL in a calibrated flask.

Pharmacopeial standard sample of lisinopril dihydrate was provided by Sigma-Aldrich (≥ 98%, HPLC).

The used dosage forms of lisinopril: Lisinopril – Astrapharm (Ukraine) (20 mg), Lisinopril-KRKA (Slovenia) (20 mg), Lisinopril-Teva (Germany) (20 mg).

Spectrophotometric method I

Proposed procedure for the determination of lisinopril with ninhydrin

Different aliquots of 100 μg/mL lisinopril methanol solution (40–60 μg/mL) were accurately measured and transferred in heating tubes. 1.1 mL of 0.2% solution of ninhydrin was added to each tube. The mixture was kept in a water bath at 95 ± 2 °C for 25 minutes, then cooled to room temperature and transferred into a 25 mL volumetric flask. The volume was made up to the mark by adding water. The absorbance was measured at 400 nm against the reagent blank, which was similarly prepared by omitting the drug. The calibration curve was performed by plotting the measured absorbance values versus concentration.

Procedure for pharmaceutical formulation for the determination of lisinopril with ninhydrin

Twenty tablets were accurately weighed and powdered. A quantity of powder containing 25 mg of lisinopril was transferred into a 25 mL volumetric flask with 15 mL methanol. The mixture was shaken for 15 min, diluted to volume with methanol and then filtered using 0.2 μm Nylon

filter membrane. The filtrate was subsequently subjected to analysis using the above described procedure.

Spectrophotometric method II

Proposed procedure for the determination of lisinopril with copper (II) sulfate

Different aliquots of 10 mg/mL lisinopril aqueous solution (0.5–2.1 mg/mL) were accurately measured and transferred into a 25 mL volumetric flask. 10.0 mL of 0.02 M solution of copper (II) sulfate was added to each tube. The volume was made up to the mark by adding water. The absorbance was measured at 730 nm against the reagent blank, which was similarly prepared by omitting the drug. The calibration curve was performed by plotting the measured absorbance values versus concentration.

Procedure for pharmaceutical formulation for the determination of lisinopril with copper (II) sulfate

Thirty tablets were accurately weighed and powdered. A quantity of powder containing 0.37 g of lisinopril was transferred into a 50 mL volumetric flask with 35 mL water. The mixture was shaken for 15 min, diluted to volume with water and then filtered using 0.2 µm Nylon filter membrane. The filtrate was subsequently subjected to analysis using the above described procedure. Aliquots of 5 mL lisinopril aqueous solution was accurately measured and transferred into a 25 mL volumetric flask. 10.0 mL of 0.02 M solution of copper (II) sulfate was added to each tube. The volume was made up to the mark by adding water. The absorbance was measured at 730 nm against the reagent blank, which was similarly prepared by omitting the drug. The calibration curve was performed by plotting the measured absorbance values versus concentration.

Results and discussion

Method development

Spectrophotometric method I

The ninhydrin has been known as a reagent for the detection of amino acids and amines for many years and therefore, a number of theories have been put forward to explain the mechanism of its reaction. It was suggested that the reactions of ninhydrin with amine, amino acids and imino acids all proceed by the same mechanism (McCaldin 1960) to give diketohydrindylidene–diketohydrindamine. This compound would further react with amino group to give the product which absorbed maximally at 400 nm and 560 nm. The optimum conditions for determination of lisinopril were established via a number of preliminary experiments. Lisinopril interacts with ninhydrin in aqueous medium via oxidative deamination of the primary aliphatic amino group of the lisyne rest contained in the lisinopril molecule followed by the condensation of the reduced ninhydrin to form the colored reaction complex with λmax at 400 nm and 560 nm. Results of experiments suggested that a higher sensitivity could be achieved at λmax 400 nm, which was selected for the following studies (Fig. 2 and Scheme I).

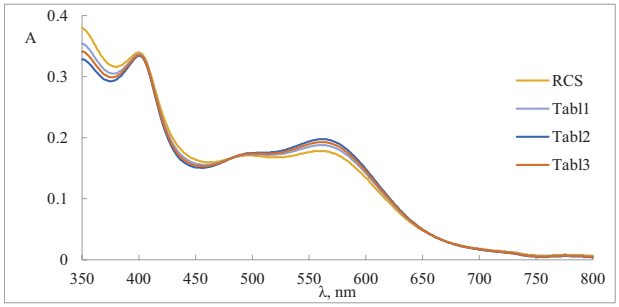
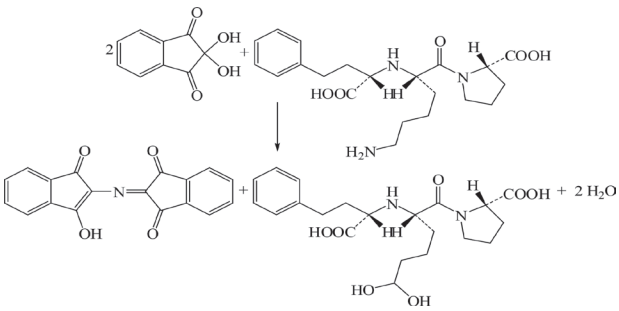


Figure 2. Absorption spectrum of lisinopril for method I.



Scheme I. Suggested reaction pathway between lisinopril and ninhydrin (Sbârcea et al. 2014).

Different parameters such as the temperature, heating time, reagents concentration have been analyzed, in order to render the optimal conditions for reaction. It has been noted that the complete color development was attained at 95 ± 2 °C. Optimum reaction time has been determined by heating the reaction mixture on a water bath at 95 ± 2 °C. A heating time of 25 minutes was found as optimal for the development of the purple color product (Fig. 3).

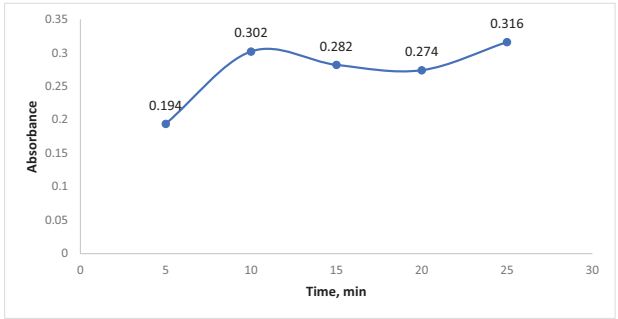


Figure 3. Effect of heating time on the formation of coloured product.

In order to investigate the effect of ninhydrin concentration on the reaction product color, the change in absorbance generated by varying the concentration of ninhydrin on fixed concentration of lisinopril (40 µg/mL) has

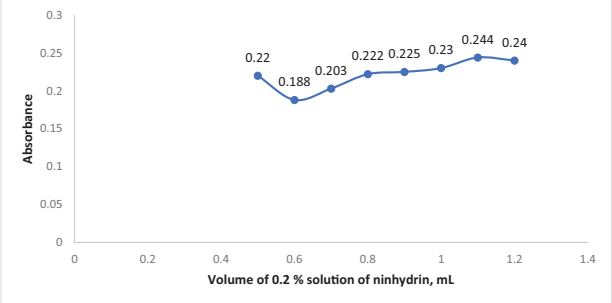


Figure 4. Effect of ninhydrin concentration on the absorbance at λmax of the coloured product.

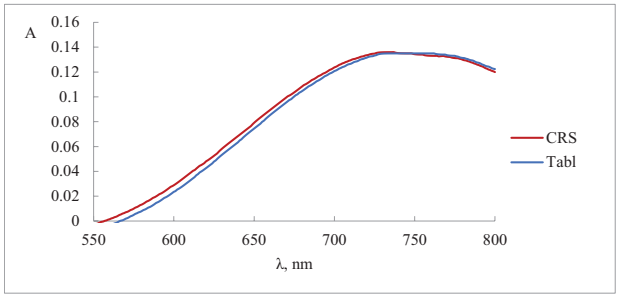


Figure 5. Absorption spectrum of lisinopril for method II.

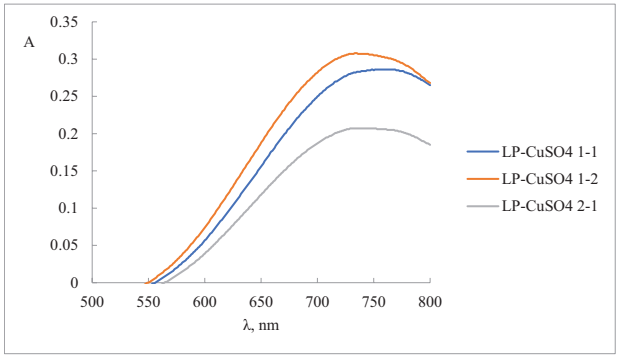


Figure 6. The absorption spectra for the blue end product in terms of study Job's method.

been measured against reagent blank. The optimum value was found to be 1.1 mL of 0.2% ninhydrin (Fig. 4).

To establish the analytical sensitivity of valsartan with ninhydrin, the sensitivity of the reaction was calculated. The molar absorption index (ε) was 2.44×10^3, the specific absorption (a) was 6.02×10^{-1}, and the Sendel coefficient (Ws) was 1.66×10^{-1}.

Spectrophotometric method II

In neutral media lisinopril forms with Cu^{2+} ions a blue complex compound. Figure 5 shows the spectrum of this compound with an absorption maximum at λ = 730 nm. Schemes II, III present proposal of the reaction pathway between lisinopril and copper (II) sulfate and suggested reaction mechanism for reaction between lisinopril and copper (II) sulfate.

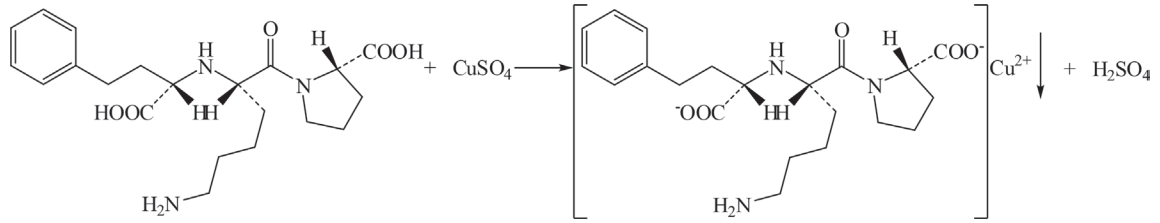
The stoichiometry of the reaction was determined using Job's method of continuous variation (Job 1936). Master equimolar solutions (1×10^{-3} M) of copper (II) sulfate with lisinopril were prepared. The method revealed 1:2 ratio (copper (II) sulfate:lisinopril). The results obtained from molar ratio studies were in agreement with the suggested reaction mechanism (Scheme III) (Fig. 6).

To establish the analytical sensitivity of valsartan with copper (II) sulfate, the sensitivity of the reaction was calculated. The molar absorption index (ε) was 0.13×10^3, the specific absorption (a) was 3.08×10^{-3}, and the Sendel coefficient (Ws) was 2.40×10^{-3}.

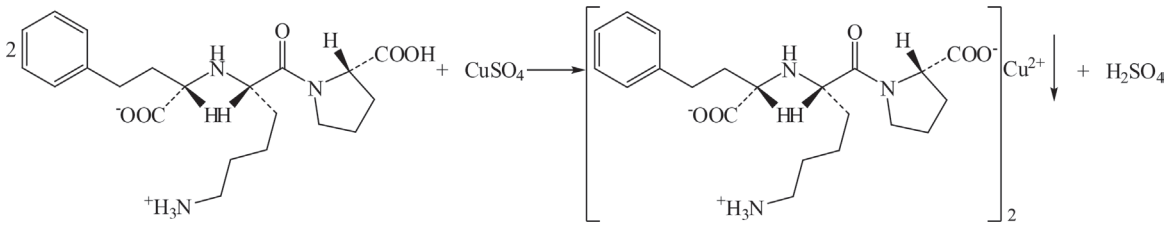
Method validation

Linearity

Beer's law limit, molar absorptivity, detection limit, regression equation and correlation coefficient were obtained by least square treatment of results (ICH 2005). The linear relationship was found between absorbance at λmax and concentration of drug in the range 40–60 μg/mL



Scheme II. Proposal of the reaction pathway between lisinopril and copper (II) sulfate.



Scheme III. Suggested reaction mechanism for reaction between lisinopril and copper (II) sulfate.

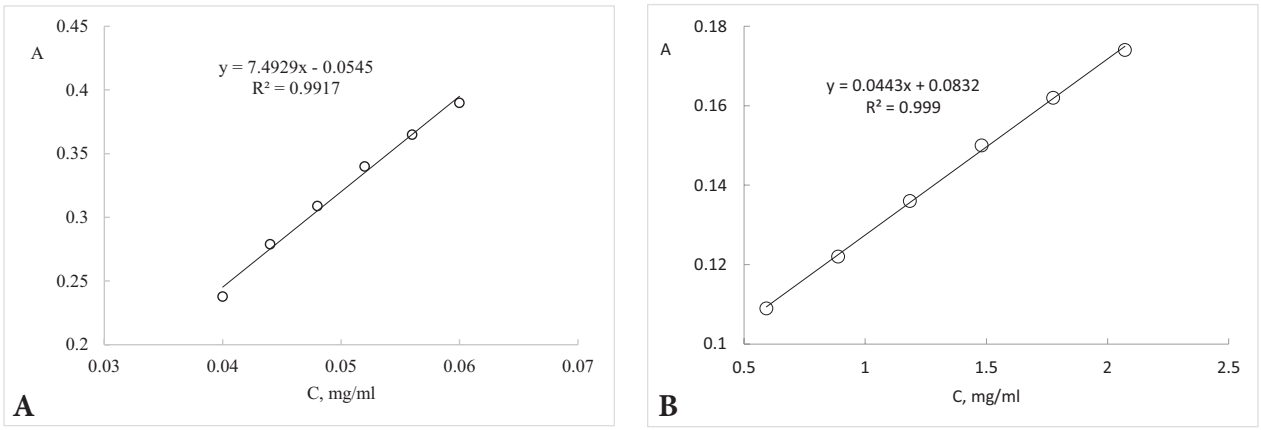


Figure 7. (**A**) Calibration curve (Method I) (**B**) Calibration curve (Method II).

Table 1. Intra-day and inter-day accuracy and precision.

Method	Lisinopril taken, µg/mL (Method I), mg/mL (Method II)	Intra-day accuracy and precision			Inter-day accuracy and precision		
		Lisinopril found, µg/mL (Method I), mg/mL (Method II)	RE, %	RSD, %	Lisinopril found, µg/mL (Method I), mg/mL (Method II)	RE, %	RSD, %
I	40	39.97	0.65	1.09	40.11	0.74	1.06
	50	50.07	0.60	1.18	49.86	0.85	1.14
	60	60.13	1.09	1.31	60.07	0.56	1.01
II	0.59	0.5901	0.74	1.06	0.5904	0.36	1.02
	1.48	1.4795	0.49	1.53	1.4803	0.45	1.08
	2.07	2.0689	0.82	1.37	2.0692	0.51	1.04

RE – Relative error; RSD – Relative standard deviation.

(Method I) and 0.592–2.072 mg/mL (Method II). Regression analysis of Beer's law plot at 400 nm yielded the regression equation, y = 7.4929x – 0.0545 (Method I) and at 730 nm y = 0.0443x – 0.0832 (Method II). High values of correlations coefficient (R^2 = 0.9917 (Method I) and R^2 = 0.999 (Method II)) and small values of intercept validated the linearity of calibration curve and obedience to Beer's law. Calibration curves are presented in Figure 7A, B. The range of application for Method I was narrow but these results did affect other validation parameters.

Limits of detection and quantification

The ICH guidelines were followed in order to determine the LOD and LOQ. Accordingly, the method based on the standard deviation of the response and the slope has been applied, so that 3.3 and 10 times the standard deviation values of y-intercept of regresion line and the regression equation were used to calculate the LOD and LOQ. The LOD and LOQ values were calculated to be 6.91 µg/mL and 23.01 µg/mL respectively (Method I) and 0.11 mg/mL and 0.36 mg/mL respectively (Method II).

Selectivity

The proposed methods were tested in order to assess its selectivity using the artificial mixture for analysis. It has been confirmed that the measured absorbance was only produced by the analyte. A synthetic mixture was prepared, containing lisinopril (20 mg), calcium hydrogen phosphate, mannitol (E 421), corn starch, magnesium stearate, colloidal anhydrous silica. The extract was yielded according to the procedure that was described for tablets and subsequently analyzed using the procedure previously described. The replicate analysis (n = 5) for a concentration level of 52 µg/mL lisinopril has yielded the % lisinopril recovery at 100.42 ± 1.25 (Method I) and for a concentration level of 1.78 mg/mL has yielded the % lisinopril recovery at 100.85 ± 1.41 (Method II), and thus revealed that the inactive ingredients did not interfere with lisinopril determination.

Precision and accuracy

Intra-day and inter-day precision values have been calculated by replicate analysis (n = 5) of calibration standard, at three different concentration levels, during the same day, and then during 5 consecutive days. The RSD (%) values of intra-day and inter-day measurements have indicated a good precision. (Table 1). Accuracy, defined as the closeness between the reference and the found values, has been evaluated, on the other hand, as percentage relative error between the measured and theoretical concentration of lisinopril. The results are presented in Table 1, and show good accuracy for developed methods.

Application to pharmaceutical formulation

The proposed methods were applied for the quantification of lisinopril in tablets pertaining to three commercial formulations. The results as presented in Table 2 reveal no significant differences between the proposed methods. The Student's t- and the F-values at 95% confidence level are less than the theoretical one, but nevertheless confirming a good agreement between the results obtained by the proposed methods.

Table 2. Determination of lisinopril formulation by the proposed methods.

Tablet brand name	Label claim, mg/tablet	Found (label claim ± SD), %	
		Method I	Method II
Lisinopril – Astrapharm (Ukraine)	20	101.075 ± 0.648 t = 1.66 F = 3.46	100.142 ± 0.311 t = 2.17 F = 3.76
Lisinopril-KRKA (Slovenia)	20	100.346 ± 0.412 t = 2.16 F = 2.87	101.205 ± 0.695 t = 1.64 F = 3.74
Lisinopril-Teva (Germany)	20	100.961 ± 0.569 t = 2.03 F = 3.38	100.975 ± 0.529 t = 1.98 F = 3.34

Tabulated t-value at 95% confidence level is 2.77;
Tabulated F-value at 95% confidence level is 6.39.

Robustness

The evaluation of robustness was carried out at the stage of development of spectrophotometric methods for the determination of valsartan during the establishment of optimal conditions for the course of reactions and determination of factors that may affect the optical density (stability of solutions over time). It was found that the studied solutions were stable for at least 45 minutes (Figs 8, 9).

Analytical eco-scale for greenness assessment

Analytical eco-scale is a semi-quantitative assessment tool commonly used for examining the greenness of analytical methods in a comparative manner (Van Aken et al. 2006; Peleshok et al. 2021b, 2021c; Gałuszka et al. 2012). It is based on assigning a numerical score, penalty points, for every step in the whole analytical method of analysis that may affect the green system such as solvents, reagents, their amounts, energy consumption, occupational risk and waste generated hazards.

Table 3 summarizes the results of developed methods found to be an excellent green analysis with a score of 89 (Method I) and 93 (Method II).

Conclusion

Two simple, rapid and green spectrophotometric methods were developed for the determination of lisinopril medicines. The determination was based on the reaction of the primary amino group of the lisinopril with ninhydrin in aqueous medium (Method I) and reaction on the carboxylic group of the lisinopril with copper (II) sulfate (Method II). Optimal spectrophotometric conditions were established. As a result of calculations of analytical indicators of sensitivity of reactions it was established that reaction of valsartan with ninhydrin has higher sensitivity, than reaction of valsartan with copper (II) sulphate that was testified by high value of molar coefficient of absorption and low value of an opening minimum. The proposed methods were validated for selectivity, linearity, limits of detection and quantification, precision and accuracy. The results of the assay of medicines of the developed methods are highly reliable and reproducible and are in good agreement with the label claim of the drugs. The developed methods can help research studies, quality control and routine analysis with lesser resources available.

Table 3. Analytical eco-scale for greenness assessment of the developed spectrophotometric methods.

Parameters	Penalty points (PP)	
	Method I	Method II
Reagents		
Methanol	4	–
Water	–	0
Ninhydrin	1	–
Copper (II) sulfate	–	1
Energy consumption	1	1
Occupational hazards	0	
Waste	5	5
Total penalty points (PP)	11	7
Analytical Eco-scale score	89	93
Comment	Excellent green analysis	Excellent green analysis

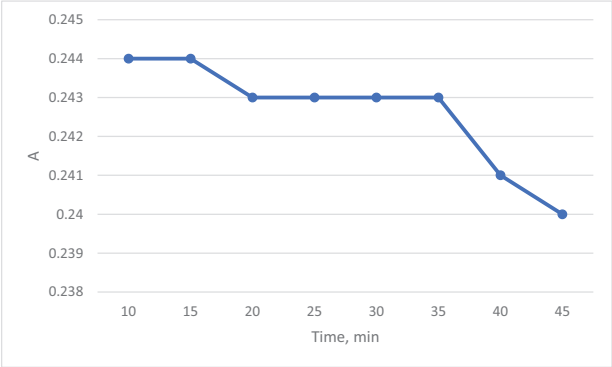


Figure 8. Graph of the dependence of the adsorption of the reaction product of valsartan with ninhydrin on time.

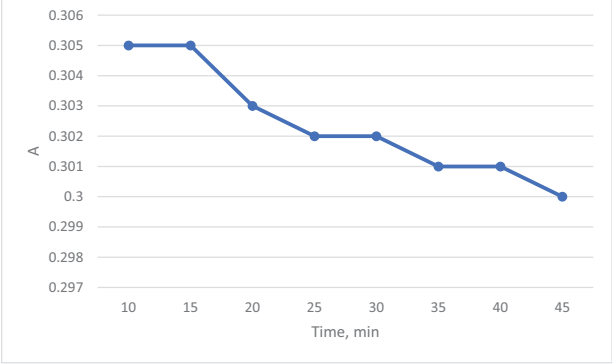


Figure 9. Graph of the dependence of the adsorption of the reaction product of valsartan with copper (II) sulfate on time.

Acknowledgements

Authors are grateful to the Ministry of Health of Ukraine Fund for providing scholarship for studies related to solutions for development of original combinations of antihypertensive agents, their analysis and standardization (0120U104201 (№509 date 24.02.2020)).

References

Andreas T, Bairachtari K, Georgarakis M (2003) Development of a liquid chromatography–mass spectrometry method for monitoring the angiotensin converting enzyme inhibitor lisinopril in serum. Journal of Chromatography B 783: 425–432. https://doi.org/10.1016/S1570-0232(02)00704-3

Arayne MS, Sultana N, Zuberi MH, Siddiqui FA, Haroon U (2013) Simultaneous determination of metformin, captopril, lisinopril, and enalapril by RP-HPLC: its applications in dosage formulations and in human serum. Medicinal Chemistry Research 22: 5717–5722. https://doi.org/10.1007/s00044-013-0501-z

Basavaiah K, Tharpa K, Hiriyanna SG, Vinay KB (2009) Spectrophotometric determination of lisinopril in pharmaceuticals using ninhydrin – a modified approach. Journal of Food and Drug Analysis 17: 93–99. http://lawdata.com.tw/File/PDF/J991/A04971702_093.pdf

Beasley CA, Shaw J, Zhao Z, Reed RA (2005) Development and validation of a stability indicating HPLC method for determination of lisinopril, lisinopril degradation product and parabens in the lisinopril extemporaneous formulation. Journal of Pharmaceutical and Biomedical Analysis 37(3): 559–567. https://doi.org/10.1016/j.jpba.2004.11.021

Chauhan V, Prajapati ST, Patel CN (2011) A validated RP-HPLC method for simultaneous estimation of amlodipine and lisinopril in pharmaceutical dosage form. International Journal of Pharmaceutical Sciences and Research 2: 1712–1715. https://doi.org/10.13040/IJPSR.0975-8232.2(7).1712-15

Drapak I, Zimenkovsky B, Perekhoda L, Kovalenko S, Logoyda L (2019a) LC-MS/MS method development and validation for the determination of cardiazol in human plasma. International Journal of Applied Pharmaceutics 11: 380–385. https://doi.org/10.22159/ijap.2019v11i4.33482

Drapak I, Zimenkovsky B, Perekhoda L, Seredynska N, Demchenko A (2019b) Search for angiotensin ii receptor antagonists among 4-aryl-n-(aryl)-3-(prop-2-en-1-yl)-2,3-dihydro-1,3-thiazol-2-imine derivatives. Pharmacia 66: 181–186. https://doi.org/10.3897/pharmacia.66.e36808

European Pharmacopoeia (2020) European Pharmacopoeia (10 th edn.). https://www.edqm.eu/en/european-pharmacopoeia-ph-eur-10th-edition

Gałuszka A, Konieczka P, Migaszewski ZM, Namiesnik J (2012) Analytical Eco-Scale for assessing the greenness of analytical procedures. Trends in Analytical Chemistry 37: 61–72. https://doi.org/10.1016/j.trac.2012.03.013

El Gindy A, Ashour A, Abdel-Fattah L, Shabana MM (2001) Spectrophotometric, Spectrofluorimetric and LC determination of lisinopril. Journal of Pharmaceutical and Biomedical Analysis 25: 913–922. https://doi.org/10.1016/S0731-7085(01)00376-4

El-Emam AA, Hansen SH, Moustafa MA, El-Ashry SM, El-Sherbiny DT (2004) Determination of lisinopril in dosage forms and spiked human plasma through derivatization with 7-chloro-4-nitrobenzo-2-oxa-1,3-diazole (NBD-Cl) followed by spectrophtometry or HPLC with fluorimetric detection. Journal of Pharmaceutical and Biomedical Analysis 34: 35–44. https://doi.org/10.1016/j.japna.2003.08.021

Huang J, Xu Y, Liu F, Gao S, Guo Q (2006) Developement of a liquid chromatography/tandem mass spectrometry assay for quantification of lisinopril in human plasma. Rapid Communications in Mass Spectrometry 20: 248–252. https://doi.org/10.1002/rcm.2309

ICH [International Council of Harmonisation, Expert Working Group] (2005) Validation of Analytical Procedures: Text and Methodology Q2(R1). https://www.gmp-compliance.org/files/guidemgr/Q2(R1).pdf

Ivanovic D, Medenica M, Jancic B, Knezevic N (2007) Validation of an analytical procedure for simultaneous determination of hydrochlorothiazide, lisinopril and their impurities. Acta Chromatographica 18: 143–156. https://www.infona.pl/resource/bwmeta1.element.baztech-article-BAT8-0006-0026/tab/summary

Jamakhandi CM, Javali C, Disouza JI, Chougule US, Mullani AK (2011) Spectrophotometric determination of lisinopril dosage form by condensation reaction. International Journal of Pharmacy and Pharmaceutical Sciences 3: 185–187. https://doi.org/10.1080/22297928.2012.10648282

Job P (1936) J. Ann. Chim., France, 16: 97.

Leis HJ, Fauler G, Raspotnig G, Windischhofer W (1998) Quantitative determination of the angiotensin-converting enzyme inhibitor lisinopril in human plasma by stabile isotope dilution gas chromatography/negative ion chemical ionization mass spectrometry. Rapid Commun. Mass Spectrom. 12: 1591–1594. https://doi.org/10.1002/(SICI)1097-0231(19981115)12:21%3C1591::AID-RCM368%3E3.0.CO;2-C

Leis HJ, Fauler G, Raspotnig G, Windischhofer W (1999) An improved method for the measurement of the angiotensin-converting enzyme inhibitor lisinopril in human plasma by stabile isotope dilution gas chromatography/negative ion chemical ionization mass spectrometry. Rapid Communications in Mass Spectrometry 13: 650–653. https://doi.org/10.1002/(SICI)1097-0231(19990430)13:8%3C650::AID-RCM536%3E3.0.CO;2-X

Lopez EO, Parmar M, Pendela VS, Terrell JM (2021) Lisinopril. StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK482230/

McCaldin DJ (1960) The chemistry of ninhydrin. Chemical Reviews 60: 39–51. https://doi.org/10.1021/cr60203a004

Naveed S, Sultana N, Arayne MS (2012) Simultaneous determination of lisinopril and H_2 antagonists in API, formulations and human serum by using two different HPLC systems. Medicinal Chemistry Research 21: 4037–4042. https://doi.org/10.4236/ajac.2012.32021

Peleshok K, Piponski M, Kovalenko S, Ahmed H, Abdel-Megied A, Ezike OF, Logoyda L (2021a) New liquid chromatography assays for simultaneous quantification of antihypertensives atenolol and valsartan in their dosage forms. Journal of Separation Science 44: 565–575. https://doi.org/10.1002/jssc.202000859

Peleshok K, Poliak O, Kryskiw L, Agyemang Sarpong, Zarivna N, Korobko D, Zahrychuk H, Horlachuk N, Sverstiuk A, Levytska L, Logoyda L (2021b) Development and validation of spectrophotometric method for simultaneous estimation of valsartan and atenolol in binary mixtures: aplication to tablets analysis. Pharmakeftiki 33: 52–60. https://www.hsmc.gr/wp-content/uploads/2015/12/issue_1_2021n2.pdf

Peleshok K, Piponski M, Ajie EA, Poliak O, Zarivna N, Denefil O, Logoyda L (2021c) Novel HPLC-UV method for simultaneous determination of valsartan and atenolol in fixed dosage form; Study of green profile assessment. Pharmacia 68: 43–51. https://pharmacia.pensoft.net/article/53631/

Rahman N, Anwar N, Kashif M (2005a) Application of π-acceptors to the spectrophotometric determination of lisinopril in commercial

dosage forms. Il Farmaco 60: 605–611. https://doi.org/10.1016/j.farmac.2005.04.011

Rahman N, Singh M, Hoda MdN (2005b) Optimized and validated spectrophotometric methods for the determination of lisinopril in pharmaceutical formulation using ninhydrin and acid ascorbic. Journal of the Brazilian Chemical Society 16: 1001–1009. https://doi.org/10.1590/S0103-50532005000600018

Sbârcea L, Udrescu L, Drăgan L, Trandafirescu C, Szabadai Z, Bojiță M (2014) Spectrophotometric method for lisinopril determination using ninhydrin. Farmacia 62: 107–118. https://farmaciajournal.com/arhiva/201401/art-10-sbarcea%20107-118.pdf

Shulyak N, Piponski M, Kovalenko S, Bakovska Stoimenova T, Drapak I, Piponska M, Rezk M, Donkor Abbeyquaye A, Oleshchuk O, Logoyda L (2021) Chaotropic salts impact in HPLC approaches for simultaneous analysis of hydrophilic and lipophilic drugs. Journal of Separation Science 44: 2908–2916. https://doi.org/10.1002/jssc.202100168

Sultana N, Arayne MS, Naveed S (2011) Validated method for the simultaneous determination of lisinopril, pravastatin, atorvastatin and rosuvastatin in API, formulations and human serum by RP-HPLC. Chinese Journal of Chemistry 29: 1216–1220. https://doi.org/10.1002/cjoc.201190226

Van Aken K, Lucjan Strekowski L, Patiny L (2006) EcoScale, a semi-quantitative tool to select an organic preparation based on economical and ecological parameters. The Beilstein Journal of Organic Chemistry 2: 1–7. https://doi.org/10.1186/1860-5397-2-3