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Simultaneous determination of Nifuroxazide and Drotaverine hydrochloride in pharmaceutical preparations by bivariate and multivariate spectral analysis

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Abstract

The quantitative predictive abilities of the new and simple bivariate spectrophotometric method are compared with the results obtained by the use of multivariate calibration methods [the classical least squares (CLS), principle component regression (PCR) and partial least squares (PLS)], using the information contained in the absorption spectra of the appropriate solutions. Mixtures of the two drugs Nifuroxazide (NIF) and Drotaverine hydrochloride (DRO) were resolved by application of the bivariate method. The different chemometric approaches were applied also with previous optimization of the calibration matrix, as they are useful in simultaneous inclusion of many spectral wavelengths. The results found by application of the bivariate, CLS, PCR and PLS methods for the simultaneous determinations of mixtures of both components containing 2–12 $\mu g\ ml^{-1}$ of NIF and 2–8 $\mu g\ ml^{-1}$ of DRO are reported. Both approaches were satisfactorily applied to the simultaneous determination of NIF and DRO in pure form and in pharmaceutical formulation. The results were in accordance with those given by the EVA Pharma reference spectrophotometric method.

Keywords: Nifuroxazide; Drotaverine hydrochloride; Spectrophotometry; Bivariate calibration; Multivariate calibrations

1. Introduction

Nifuroxazide (NIF) and Drotaverine hydrochloride (DRO) are formulated together in the form of Drotazide® capsule; which is used for treatment of spasmodic diarrhea. Nifuroxazide [4-hydroxybenzoic acid (5-nitro-2-furanyl methylene) [1] is used for treatment of acute and chronic-diarrhea, gastroenteritis, and colitis. Drotaverine [1-(3,4-diethoxy benzylidene)-6,7-diethoxy-1,2,3,4-tetraiso hydroquinoline [2] is a hydrochloride salt used as an effective spasmolytic drug.

NIF was determined individually by non-aqueous titration [1], aqueous titration [3], voltammetry [4–8], spectrophotometry [8,9], colorimetry [10], HPLC in pharmaceutical formulations [10], and HPLC in biological fluids [11].

On the other hand DRO was determined either individually by electrochemical methods [12,13], spectrophotometric methods [14–16] and HPLC methods [17–20], or in combination with nicotinic acid and phenazone spectrophotometrically [21], in mixture with niclosamide which depends on measuring the absorbance of the acidic solution against their alkaline solutions as a blank at 355 nm [14]. Drotaverine HCl was analyzed in presence of Nifuroxazide in pharmaceutical dosage forms by derivative spectrophotometric, densitometric and HPLC methods [22].

Bivariate calibration spectrophotometric method is a new and simple method for the resolution of binary mixtures. This method is based on the simple mathematic algorithm and it's advantage depends on the fact that there is no need to use derivatization procedures [23]. The multivariate calibration models are useful for the reduction of band overlapping errors in quantitative analysis.

In this work, a binary mixture of NIF and DRO was analyzed employing both the bivariate and multivariate methods for the simultaneous determination of each in its pharmaceutical preparation and for the comparison purpose in view of the accuracy and precision of the results.

2. Experimental

2.1. Apparatus

Shimadzu spectrophotometer, UV-Vis 1601 PC with 1 cm quartz cuvets, connected to an IBM compatible computer, with

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UVPC personal spectroscopy software version 3.7 (Shimadzu Corporation, Kyoto, Japan). All data analysis was performed using PLS-Toolbox 2.0 running under Matlab™, Version 5.3 [24].

2.2. Materials

(a) *Authentic samples*. NIF (Batch no. 20040501) and DRO (Batch No. 776773) were kindly supplied by Eva Pharm for Pharmaceuticals and Medical appliances (Giza, Egypt). Their purity was 99.53% and 99.2% respectively, according to the company analysis certificate.
(b) *Market samples*. Drotazide capsules (Batch no. 603331) each capsule was labeled to contain 200 mg NIF and 40 mg DRO (Eva Pharm for pharmaceuticals and Medical Appliances).
(c) *Chemicals and reagents*. All experiments were performed with analytical-reagent grade chemicals.
(d) *Absolute ethanol*. Spectroscopic grade (E-Merck, Darmstad, Germany).

2.3. Preparation of standards

(a) *Stock solutions*. For both NIF and DRO: Weigh accurately 50 mg pure powder, transfer into a 100 ml volumetric flask (protected from light due to photosensitivity [25]), add 75 ml absolute ethanol, shake well, and dilute to volume with absolute ethanol to prepare a 500 μg ml^{-1} stock solution.
(b) *Working solutions*. Transfer an accurately measured 20 ml volume of the stock solution into a 100 ml volumetric flask (protected from light) and dilute to volume with absolute ethanol to prepare a 100 μg ml^{-1} working solution.

2.4. Procedures

2.4.1. Bivariate method

2.4.1.1. Spectral characteristics of NIF and DRO. One milliliter of each of NIF and DRO working solution were separately transferred into a 10 ml volumetric flask (protected from light) and diluted to volume with absolute ethanol. The absorbance (Fig. 1) was recorded for each solution using absolute ethanol as the blank.

2.4.1.2. Linearity Aliquot equivalent. Aliquot equivalent to 0.2–1.2 ml of NIF working solution and 0.1–0.8 ml of DRO working solution were transferred separately into 10-ml volumetric flasks from their respective working standard solution (100 μg ml^{-1}) and completed to volume with ethanol. The spectra of NIF and DRO were recorded and stored on computer. The regression equations were computed to 229 and 287.5 nm.

2.4.1.3. Assay of laboratory-prepared mixtures. The absorption spectra of different laboratory prepared mixtures were measured at 229 and 287.5 nm. The concentrations of NIF and DRO were calculated using the parameters of the linear regression functions evaluated individually for each component at the same wavelength and substituting in the following equations:

$$C_{DRO} = \frac{m_{A2}(A_{AB1} - e_{AB1}) + m_{A1}(e_{AB2} - A_{AB2})}{m_{A2}m_{B1} - m_{A1}m_{B2}},$$

$$C_{NIF} = \frac{A_{AB1} - e_{AB1} - m_{B1}C_{DRO}}{m_{A1}}$$

where e_{AB1} and e_{AB2} are the sum of the intercepts of the linear calibration regression equations at the selected two wavelengths ($e_{AB1} = e_{A1} + e_{B1}$).

m_A and m_B are the slopes of the linear regression equations at the two selected wavelengths and C is the concentrations of NIF and DRO.

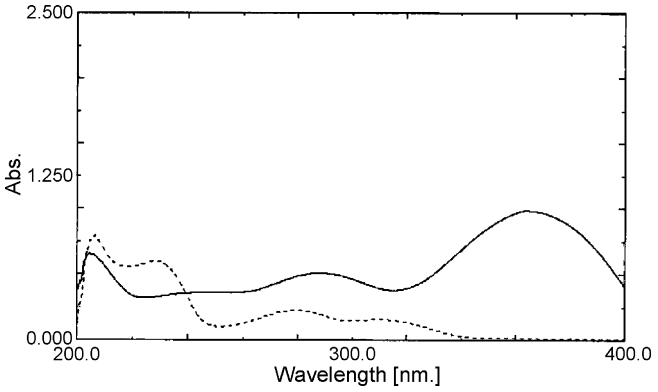

Fig. 1. Absorption spectra of Nifuroxazide (—) and Drotaverine HCl (- - - - -) 10 μg ml^{-1} each in ethanol.

2.4.2. Multivariate analysis

2.4.2.1. Construction of the training set. Nine binary mixtures of NIF and DRO were prepared in triplicate by placing different volumes of their working solutions (100 μg ml^{-1}) into 10 ml measuring flasks. The volume was completed to the mark with ethanol to reach the concentrations listed in Table 1. The absorbencies of these mixtures were measured between 200 and 400 nm at 0.2 nm intervals against ethanol as a blank.

The composition of the samples was randomly designed in order to obtain non-correlated concentration profiles. Several multivariate calibration models (CLS, PCR, and PLS) were constructed using the data obtained.

Table 1
The concentrations of different mixtures of Nifuroxazide and Drotaverine HCl used in the training set

Sample no.	Concentration (μg ml^{-1})	
	Nifuroxazide	Drotaverine HCl
1	10	2
2	9	2.2
3	11	2.2
4	11	2
5	10	2.2
6	11	1.8
7	9	1.8
8	9	2
9	10	1.8

Setting up the design [33].

Initial developed models were found to have high spectral residuals in the region from 200 to 220 nm. As a result, this region was rejected. For CLS method, construct CLS model with non-zero intercept.

2.4.2.2. Constructing the models. To build the CLS model, the computer was fed, with the absorbance and concentration matrices for training set. The calculations to obtain the K matrix were carried out for the PCR and PLS models, the training set absorbance and concentration matrices together with PLS-toolbox 2.0 software were used for calculations.

2.4.2.3. Selection of the optimum number of factors to build the PCR and PLS models. The cross validation method was used, leaving out one sample at a time, to select the optimum number of factors [26]. Given a set of 9 calibration samples the PCR and PLS calibrations were performed, and using this calibration, the concentration of the sample left out was predicted. The predicted concentrations were then compared with the actual concentrations and the root mean square error of calibration (RMSEC) was calculated. The maximum number of factors used to calculate the optimum RMSEC was selected to be 5 (half the number of samples + 1) [27]. Visual inspection was used for selecting the optimum number of factors. Three factors were found suitable for both PCR and PLS methods as shown in (Fig. 2).

2.4.2.4. Validation.

2.4.2.4.1. Construction of the validation set. Different nine mixtures of NIF and DRO were prepared by transferring different volumes of their working solutions (100 μg ml^{-1}) into 10 ml volumetric flasks and diluting to volume with absolute ethanol. The suggested models were applied to these mixtures to predict the concentrations of NIF and DRO (Table 7).

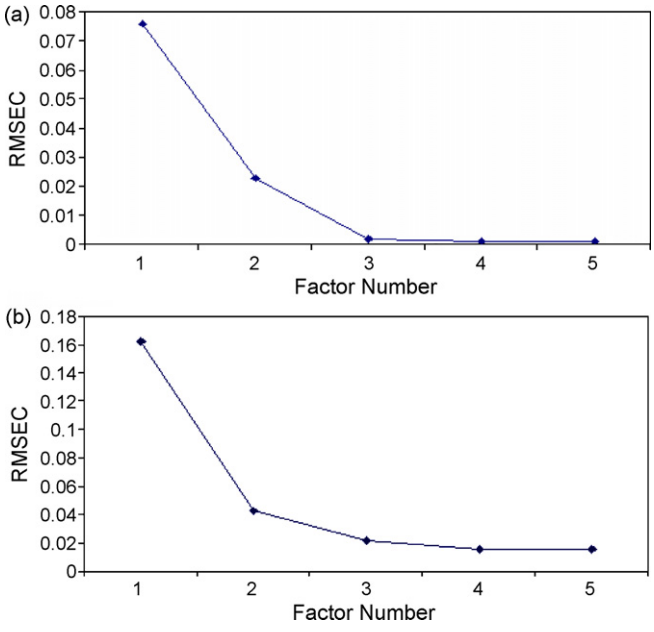

Fig. 2. (a) RMSEC plot of a calibration set prediction using cross validation (principal component regression model). (b) RMSEC plot of a calibration set prediction using cross validation (partial least squares model).

2.5. Application to pharmaceutical preparation (Drotazide® capsules)

The contents of 10 Drotazide® capsules was accurately weighed and well mixed. Then the powder equivalent to 50 mg of each NIF and DRO was weighed, transferred into two separate light protected 250 flasks, extracted with 75 ml absolute ethanol, filtered into two separate light protected 100 ml volumetric flasks and completed to volume with the same solvent. The procedure details under bivariate and multivariate methods were then followed.

2.5.1. Standard addition technique

Applied as indicated in applications to pharmaceutical preparation taking into consideration that the powder content of the capsules and that of the authentic drug of each were mixed well together before proceeding with the above mentioned procedures (Table 8).

3. Results and discussion

In a previous study [22], the influence of several variables during derivative spectroscopy, densitometry and HPLC methods were investigated for determination of Nifuroxazide and Drotaverine. In this research two methods were proposed for the simultaneous determination of Nifuroxazide and Drotaverine hydrochloride in binary mixture without prior treatment through bivariate and multivariate spectrophotometric methods. The use of this approach allowed the determination of the mixture inspite of the severe spectral overlapping as shown in Fig. 1, which preclude the possibility of simultaneous determination of Drotaverine in presence of Nifuroxazide by direct spectrophotometry.

3.1. Bivariate method

The resolution of two components by the bivariate calibration has been recently proposed [28–30]. This method is based on a simple mathematical algorithm, in which the data is used from four linear regression equations, two calibrations for each component in the binary mixture (A and B) at the two selected wavelengths (λ_1 and λ_2) to obtain two equations:

$$A_{AB1} = m_{A1}C_A + m_{B1}C_B + e_{AB1},$$

$$A_{AB2} = m_{A2}C_A + m_{B2}C_B + e_{AB2}$$

The resolution of such equations set allows the evaluation of C_A and C_B values (equations in Section 2.4.1.3).

In order to apply this method, select the signals of the two components located at six wavelengths: 216, 229, 238, 264, 287.5 and 308 nm.

The calibration curve equations and their respective linear regression coefficients are obtained directly with the aim of ensuring the linearity between the signal and the concentrations.

The slope values of the linear regression were estimated for both components at the selected wavelengths and used for determination of the sensitivity matrices K, proposed by Kaiser's

Table 2
Application of the method of Kaiser for the selection of the wavelength set for the mixture of Nifuroxazide and Drotaverine HCl

λ_1/λ_2	216	229	238	264	287.5	308
216	0	90.62	102.24	77.54	54.92	36.27
229		0	88.50	96.36	186.46	52.41
238			0	46.74	37.19	46.85
264				0	23.23	14.38
287.5					0	8.76
308						0

The absolute values of determinants of sensitivity ($K \times 10^{-5}$).

method [23]. A series of sensitivity matrices K, were created for each binary mixture and for every pair of pre-selected wavelengths.

$$K = \begin{pmatrix} m_{A1} & m_{B1} \\ m_{A2} & m_{B2} \end{pmatrix}$$

where $m_{A1,2}$, $m_{B1,2}$ are the sensitivity parameters (slop) of the regression equations of A and B at the two selected wavelengths (λ_1 and λ_2). The determinants of these matrices were calculated (Table 2). The wavelength set was selected for which the highest matrix determinant value was obtained. Thus for the bivariate determination of NIF and DRO wavelength 229 and 287.5 nm were used. At these wavelengths the one-component calibration curves were obtained in the range 2–12 μg ml^{-1} for NIF and 2–8 μg ml^{-1} for DRO. The linear regression calibration formula used for the bivariate algorithm are presented in Table 3.

The proposed method is valid for the simultaneous determination of NIF and DRO in different laboratory prepared mixtures, with mean percentage recoveries of 99.94 ± 1.44 for NIF and 100.50 ± 1.61 for DRO (Table 4). It has been applied for the determination of the two drugs in Drotazide capsules and the validity was further assessed by applying the standard addition technique (Table 5).

Furthermore, statistical analysis of the results obtained by the proposed method and the reference method [31] were compared. The t and F values were computed by a Microsoft Excel program and found to be less than tabulated values. This indicates no significant differences with respect to accuracy and precision (Table 6). The results obtained indicate that additives present in the capsules did not interfere with the studied mixture.

3.2. Multivariate method

In this method, different chemometric approaches were applied for the determination of NIF and DRO binary mixture; namely CLS, PCR and PLS. These multivariate calibrations were useful in spectral analysis because the simultaneous inclusion of many spectral wavelengths instead of single wavelength greatly improved the precision and predictive ability [32].

The CLS method requires all components in the calibration samples to be known, while the selection of the optimum number of factors for the PCR and PLS techniques was a very important step before constructing the models. Visual inspection could be used for determining the optimum number of factors [27]. In this study, the leave one out cross validation method was used and the RMSEC values of different developed models were compared. Three factors were found suitable for both PCR and PLS (Fig. 2). To validate the prediction ability of the suggested models, they were used to predict the concentrations of NIF and DRO in binary mixture in the validation set (Table 7).

Table 3
Linear regression calibration formula used for the bivariate algorithm

Binary mixture	Component	Calibration equation	
		λ = 229 nm	λ = 287.5 nm
Nifuroxazide and Drotaverine HCl	Nifuroxazide	$Y = 0.0435X + 0.0131$[a], $R = 0.9996$	$Y = 0.0208X + 0.007$ $R = 0.9994$
	Drotaverine HCl	$Y = 0.0275X - 0.0011$, $R = 0.9992$	$Y = 0.056X - 0.0234$, $R = 0.9993$

[a] Where Y is the absorbance value at 229 nm and at 287.5 nm. X the concentration in μg ml^{-1} and r is the correlation coefficients.

Table 4
Determination of Nifuroxazide and Drotaverine HCl in Laboratory–prepared mixtures by the Bivariate method

Mixture number	Nifuroxazide			Drotaverine HCl		
	Claimed taken (μg ml^{-1})	Found[a] (μg ml^{-1})	Recovery (%)	Claimed taken (μg ml^{-1})	Found (μg ml^{-1})	Recovery (%)
1 (1:1)	6.0	6.075	101.25	6.0	6.052	100.87
2 (5:3)	10.0	9.980	99.80	6.0	5.965	99.42
3 (3:5)	3.0	3.028	100.93	5.0	4.971	99.42
4 (1:4)	2.0	1.962	98.10	8.0	8.054	100.68
5 (5:1)[b]	10.0	9.943	99.43	2.0	2.031	101.55
6 (1:2)	4.0	3.931	98.28	8.0	7.867	98.34
7 (2:1)	8.0	8.141	101.76	4.0	4.128	103.20
Mean ± S.D.[c] (%)			99.94 ± 1.439			100.50 ± 1.610

[a] Average of three experiments.
[b] Ratio present in Drotazide capsules.
[c] S.D.: standard deviation.

Table 5
Application of standard addition technique to the analysis of Nifuroxazide and Drotaverine HCl in Drotazide capsule by Bivariate method

Drotazide capsule	Nifuroxazide				Drotaverine HCl			
	Found[a] (%)	Pure added ($\mu g\,ml^{-1}$)	Pure found ($\mu g\,ml^{-1}$)	Recovery (%)	Found (%)	Pure added ($\mu g\,ml^{-1}$)	Pure found ($\mu g\,ml^{-1}$)	Recovery (%)
Batch	96.12	3	3.015	100.50	105.04	2	2.061	103.05
no.		4	3.891	97.28		3	2.939	97.97
603331		5	4.931	98.62		4	4.006	100.15
		6	5.986	99.77		5	4.972	99.44
Mean ± S.D.				99.04 ± 1.407				100.15 ± 2.134

[a] Average of six experiments.

Table 6
Statistical analysis of the results obtained by the proposed Bivariate method and the reference method for Drotazide capsules (Batch No. 603331)

Parameters	The proposed bivariate calibration method		Manufacturer method [31]	
	Nifuroxazide	Drotaverine HCl	Nifuroxazide	Drotaverine HCl
Mean + S.D. (%)	96.12 ± 1.41	105.04 ± 1.62	95.49 ± 1.74	104.13 ± 2.01
N	6	6	6	6
Variance	1.988	2.624	3.020	4.050
t (2.23)*	0.576	0.429	–	–
F (5.05)*	1.519	1.543	–	–

* The values in parentheses are corresponding to the theoretical values of *t* and *F* at ($p = 0.05$).

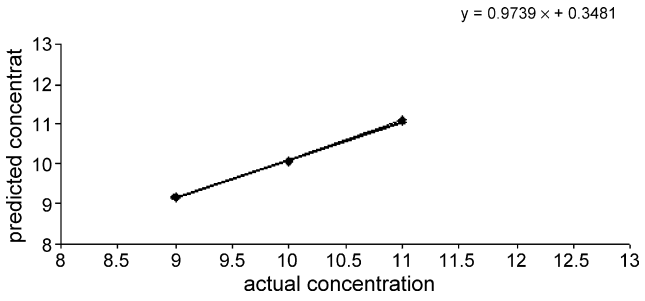

Fig. 3. Predicted concentration vs. actual concentration of Nifuroxazide using partial least squares (PLS).

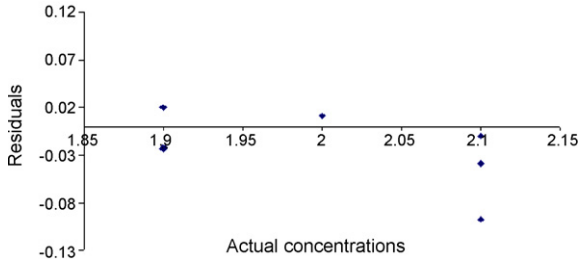

Fig. 4. Concentration residuals vs. known concentrations of Drotaverine HCl using partial least squares (PLS).

Table 7
Results obtained for the analysis of different laboratory prepared mixtures of Nifuroxazide and Drotaverine HCl by the multivariate spectral analysis methods

Sample no.	Concentration ($\mu g\,ml^{-1}$)		CLS recovery (%)		PCR recovery (%)		PLS recovery (%)	
	NIF	DRO	Nifuroxazide	Drotaverine	Nifuroxazide	Drotaverine	Nifuroxazide	Drotaverine
1	10	2.0	97.90	100.58	98.50	99.30	99.30	99.65
2	9	2.1	98.00	100.50	100.44	100.90	100.65	100.67
3	11	2.1	98.00	100.50	99.27	99.09	98.44	100.15
4	11	2.0	102.40	101.56	99.36	100.50	98.08	100.91
5	10	2.1	101.60	102.00	101.00	99.55	99.99	99.75
6	11	1.9	100.80	100.50	100.91	101.89	99.48	101.26
7	9	1.9	101.20	100.26	99.67	100.56	101.27	100.23
8	9	2.0	99.70	101.00	100.00	100.50	100.50	101.21
9	10	1.9	101.90	99.86	100.80	98.83	99.97	101.00
Mean ± S.D. (%)			100.12 ± 1.75	100.75 ± 0.66	99.99 ± 0.86	100.12 ± 0.99	99.74 ± 1.03	100.54 ± 0.61

*Average of three experiments.

Table 8
Summary of results obtained by applying the diagnostic tools for model validation of the multivariate spectral analysis methods

Validation parameters	Multivariate methods					
	CLS		PCR		PLS	
	Nifuroxazide	Drotaverine	Nifuroxazide	Drotaverine	Nifuroxazide	Drotaverine
A. Predicted vs. known concentrations plot						
1. Slope	0.9754	0.9692	0.9857	0.9694	0.9739	0.9294
2. Intercept	0.0417	0.5261	0.0246	0.5223	0.3481	0.1298
3. Correlation coefficient	0.9992	0.9996	0.9993	0.9995	0.9998	0.9999
B. Residuals vs. actual concentration plot						
1. ±error in prediction	±0.124	±0.146	±0.086	±0.156	±0.108	±0.087
C. RMSEP value	2.132×10^{-3}	3.72×10^{-3}	0.0419	0.0342	0.0481	0.01606

MSEP: press/n, press = sum of $(y - y')^2$.
RMSEP: root mean square error of prediction.

Table 9
Quantitative determination of Nifuroxazide and Drotaverine HCl in Drotazide® capsules by the proposed multivariate spectral analysis methods

Drotazide capsule	CLS, found (%) ± S.D.[a]		PCR, found (%) ± S.D.[a]		PLS, found (%) ± S.D.[a]	
	Nifuroxazide	Drotaverine	Nifuroxazide	Drotaverine	Nifuroxazide	Drotaverine
Batch no. 603331	95.02 ± 1.54	105.98 ± 0.87	95.41 ± 0.68	106.12 ± 0.83	95.44 ± 0.698	106.22 ± 0.63

[a] Average of three determinations.

For evaluations of the predictive abilities of the developed models, several diagnostic tools were used:

(a) Predictive versus actual concentration plot (model and sample diagnostic) Fig. 3 is a sample graph showing this relation for NIF by PLS method.
(b) Concentration residuals versus actual concentration plot (model and sample diagnostic) Fig. 4 is a sample graph showing this relation for Drotaverine by PLS method.
(c) Root mean square error of prediction (RMSEP) (model diagnostic), the predicted concentrations of the validation samples were calculated (Table 8).

Table 10
Results of the standard addition technique for the determination of Nifuroxazide and Drotaverine HCl in Drotazide capsules by the proposed multivariate spectral analysis methods

Claimed taken (μg ml^{-1})		Pure added (μg ml^{-1})		Recovery (%) of pure added[a]					
NIF	DRO	NIF	DRO	CLS		PCR		PLS	
				NIF	DRO	NIF	DRO	NIF	DRO
5	1	4	0.8	99.20	99.54	99.89	100.56	100.24	99.21
		5	0.9	99.67	100.47	100.37	99.71	99.71	100.35
		6	1.0	101.14	98.69	101.23	101.13	100.43	99.38
Mean ± S.D. (%)				100.00 ± 1.01	99.57 ± 0.89	100.50 ± 0.68	100.57 ± 0.86	100.13 ± 0.37	99.65 ± 0.62

[a] Average of three determinations.

Table 11
Statistical analysis of the results obtained by applying the proposed multivariate spectral analysis and the spectrophotometric manufacturer method [31] for the analysis of mixtures of Nifuroxazide and Drotaverine hydrochloride in pure forms

Parameters	The proposed methods						Manufacturer method	
	CLS		PCR		PLS		NIF	DRO
	NIF	DRO	NIF	DRO	NIF	DRO		
Mean	100.12	100.75	99.99	100.12	99.74	100.54	100.93	101.3
S.D.	1.75	0.66	0.96	0.99	1.03	0.61	1.84	1.06
N	9	9	9	9	9	9	6	6
Student's t (2.16)	0.885	0.206	0.488	0.638	1.66	0.3299	–	–
t test (3.69)	1.11	2.58	3.67	1.15	3.19	3.02	–	–

The values in parentheses corresponding to the theoretical values of t and F at ($p = 0.05$).

The chemometric methods CLS, PCR and PLS were applied successfully to the analysis of the binary mixture in capsules (Table 9). To assess the accuracy of the methods, standard addition technique was carried out. The recoveries shown in Table 10 are satisfactory indicating that the problem of interference of the mixture or additives could be solved successfully. Statistical analysis of the results obtained by the suggested methods was carried out against the reference company method [31]. Table 11 shows that the calculated t and F-values were less than the theoretical ones, indicating no significant differences in accuracy and precision.

4. Conclusion

Both bivariate and multivariate methods were found to provide good results in the resolution of the binary mixture of Nifuroxazide and Drotaverine hydrochloride, whose spectra are strongly overlapping. The resolution of synthetic mixtures by application of the studied methods gives rise to acceptable recovery values in both cases. The proposed methods can be used without any preconcentration or separation process in pharmaceutical preparation.

The multivariate methods have been developed to compare the accuracy and precision with the bivariate method (single wavelength measurements) in the analysis of synthetic binary mixtures and pharmaceutical preparations containing Nifuroxazide and Drotaverine HCl. Comparison between standard deviation of the methods (S.D.) assure the preference of the multivariate methods to the bivariate method in term of precision. It is obvious that the information obtained from the whole spectrum allows to define the sample better than results obtained from a single wavelength only, such as spectral differentiation.

References

[1] Pharmacopee Francaise, Xeme ed., L'ADRAPHARM, Paris, 1985.
[2] The Merck index, 13th ed., Merck research Laboratories Division of MERCK & CO., INC. Whitehouse station, NJ, 2001.
[3] The British Pharmacopoeia, Her Majesty's Stationary Office, London, 2003.
[4] S.N. Yugandhar, S.K. Reddy, R.P.R. Kumar, Indian Drugs 36 (8) (1999) 509.
[5] A. Radi, M.A. El Ries, J. Anal. Sci. 15 (4) (1999) 385.
[6] A. Radi, Fresenius J. Anal. Chem. 364 (6) (1999) 590.
[7] W. Buchberger, G. Niessner, R. Bakry, Fresenius J. Anal. Chem. 362 (2) (1998) 205.
[8] E. Szuminska, A. Cisak, Acta Pol. Pharm. 47 (1–2) (1990) 1.
[9] M.I. Toral, M. Paine, P. Leyton, P. Richter, J. AOAC Int. 87 (6) (2004) 1323.
[10] K.M. Emara, I.H. Refaat, O.H. Abdlmageed, Egypt J. Pharm. Sci. 35 (1994) 313.
[11] P.R. Guinebault, M. Broquaire, R.A. Braithwaite, J. Chromatogr. 204 (1981) 329.
[12] M. Fulop, K. Kaloy, A. Toth, Magy-Kem. Foly. 92 (10) (1986) 468.
[13] H. Ibrahim, Y.M. Issa, H.M. Abu-Shawish, Anal. Lett. 38 (1) (2005) 111.
[14] H.G. Daabees, Anal. Lett. 33 (2000) 639.
[15] V.A. Knaub, V.A. Kartashov, Farmatsiya (Moscow) 38 (3) (1989) 46.
[16] J. Geher, E. Szabo, J. Pharm. Biomed. Anal. 6 (1988) 757.
[17] O.O. Bolaji, C.O. Onyeji, F.O. Ogungbamila, F.A. Ogunbona, E.O. Ogunlana, J. Chromtogr. Biomed. Anal. 6 (1993) 757.
[18] J.K. Llla, M.V. Shah, M.B. Jain, A.M. Sharma, J. Pharm. Biomed. Anal. 11 (1993) 385.
[19] J. Mezei, S. Kuttel, P. Szentmiklosi, S. Marto, I. Racz, J. Pharm. Sci. 73 (1984) 1489.
[20] S. Dyderski, E. Grzeskowiak, L. Drobnik, E. Szalek, M. Balcerkiewicz, V. Dubai, Arzneimittelforschung 54 (5) (2004) 298.
[21] J. Geher, E. Szabo, J. Pharm. Biomed. Anal. 6 (6–8) (1988) 757.
[22] F.H. Metwally, M. Abdelkawy, I.A. Naguib, J. AOAC Int. 89 (1) (2006) 78.
[23] D.L. Massart, B.G.M. Vandeginste, S.N. Deming, Y. Michotte, L. Kaufman, Chemometrics; A Textbook, Elsevier, Amsterdam, 1988, p. 124.
[24] B.M. Wise, N.B. Gallagher, PLS-Toolbox 2. 0 for Use with Matlab™, Eigenvector Research Corporation, Manson, WA, 1998.
[25] N. Boussac, M.J. Galimier, G. Dauphin, M. Madesclaire, C. Lartigue, Mirochim. Acta 141 (2003) 179.
[26] R. Kramer, Chemometric Techniques for Quantitative Analysis, Marcel Dekker Inc., New York, 1998.
[27] A. Espinosa-Mansilla, A. Munoz de la pena, F. Salinas, Anal. Chim. Acta 276 (1993) 141.
[28] P.L. Lopez-de-Alba, L. Lopez-Martinez, K. Wrobel-Kaczmarczyk, K. Wrobel-Zasada, J. Amador-Hernandez, Anal. Lett. 29 (1996) 487.
[29] P.L. Lopez-de-Alba, L. Lopez-Martinez, K. Wrobel-Kaczmarczyk, K. Wrobel-Zasada, J. Amador-Hernandez, M.L. Yepez-Murrieta, J. Pharm. Biomed. Anal. 16 (1997) 349.
[30] L. Lopez-Martinez, P.L. Lopez-de-Alba, V. Cedra-Martin, Anal. Lett. 34 (2001) 2563.
[31] Spectrophotometric manufacturer procedure (Eva Pharm for pharmaceutical and Medical Appliance) personal communication.
[32] Y. Ni, X. Gong, Anal. Chim. Acta 354 (1997) 163.
[33] R.G. Brereton, Analyst 122 (1997) 1521.