

Original article**Permanganometric determination of sumatriptan succinate in pure drug and pharmaceutical formulation****K.N. Prashanth, K. Basavaiah* and M.S. Raghu***Department of Studies and Research in Chemistry, University of Mysore,**Manasagangothri, Mysore 570006, India***Corresponding author: Tel: +91 8212419659; Fax: +91 8212516133;**E-mail address: basavaiahk@yahoo.co.in***Abstract:**

Based on the reduction of permanganate by sumatriptan succinate (STS) in acidic medium, two simple, sensitive and cost-effective methods were described for the determination of STS in bulk drug and in formulation. In titrimetry (method A), STS was oxidized by a known excess of potassium permanganate (KMnO_4) in H_2SO_4 medium followed by determination of unreacted permanganate by titration with ferrous ammonium sulphate. In spectrophotometry (method B), STS was treated with a measured excess of permanganate in acid medium and the unreacted oxidant was measured at 545 nm. The molar combining ratio in titrimetry and the optimum assay conditions were studied. Titrimetry was applicable over 1-7 mg range and the calculations were based on a 1:6 (STS: KMnO_4) molar ratio. In spectrophotometry, Beer's law was obeyed over 0.8-16.0 $\mu\text{g ml}^{-1}$ concentration range of STS. The molar absorptivity and Sandell sensitivity values are calculated to be $1.39 \times 10^4 \text{ l mol}^{-1} \text{ cm}^{-1}$ and $0.03 \mu\text{g cm}^{-2}$, respectively. The limits of detection (LOD) and quantification (LOQ) were also reported for the spectrophotometric method. The applicability of the developed methods was demonstrated by the determination of STS in pure drug as well as in commercial dosage form.

Keywords: Sumatriptan succinate; Determination; Visible spectrophotometry; Titration; Redox reaction; Potassium permanganate

Introduction

Triptans are a group of tryptamine-based drugs used in the acute treatment of migraine headaches. Sumatriptan succinate (Figure 1) is one among them and is structurally related to the neurotransmitter serotonin. Sumatriptan succinate (STS) is a 5-hydroxy-tryptamine (5-HT) receptor subtype (a member of the 5-HT_{1D} family) having only a weak affinity for 5-HT_{1A}, 5-HT_{5A}, and 5-HT₇ receptors and chemically designated as [3-[2-(dimethylamino)ethyl]-1*H*-indol-5-yl]-*N*-methylmethanesulphonamide hydrogen butanedioate [1]. STS acts by selectively binding to serotonin type-1D receptors (serotonin agonist) and rapidly terminates a migraine attack while eliminating associated symptoms such as nausea, vomiting, and light and sound sensitivity [2].

STS has official monographs in BP [1], EP [3] and USP [4] which described liquid chromatographic methods for the assay of STS. From the literature survey, it is found that high performance liquid chromatography (HPLC) has been used for the assay of STS in human plasma [5, 6], human serum [7], rabbit plasma [8] and human plasma and urine [9] whereas liquid chromatography-mass spectrophotometry (LC-MS/MS) in body fluids [10] and human plasma [11]. Several methods have been reported for the determination of STS in pharmaceuticals including UV-spectrophotometry [12-16], HPLC [17-20], ultra performance liquid chromatography (UPLC) [21], high performance thin layer chromatography (HPTLC) [16, 22], capillary electrophoresis [23], micellar electrokinetic chromatography [24] and voltammetry [25-27].

Besides, STS in pharmaceuticals have been determined by visible spectrophotometry employing different reaction schemes. Satyanarayana and Rao [28] have described two methods using *in situ* bromine, methyl

orange and indigo carmine as reagents. Based on a well-known redox reaction and employing Folin-Ciocalteu's reagent [22], the drug in pharmaceutical dosage forms was determined by Tipre and Vavia. Chloranil and acetaldehyde [29] were used as reagents for the assay of STS based on condensation reaction. Using acetaldehyde in combination with sodium nitroprusside and based on inner molecular complex formation, the drug was assayed by Kalyanaramu and Raghubabu [30]. The drug is reported to undergo oxidative coupling reaction in the presence of brucine and sodium metaperiodate based on which a method was developed by Kalyanaramu and Raghubabu [31]. The reaction between STS and sodium salt of 1,2-naphthaquinone-4-sulphonic acid (Folin reagent) yielded a brown colored chromogen [32] forming the basis for the assay of the drug. A green colored ternary complex formed by the drug with cobalt-thiocyanate was extracted into benzene and measured at 630 nm, and served as the basis of its assay [33]. Tropaeolin OOO is reported to form chloroform extractable orange-colored ion-pair with STS having an absorption maximum at 483 nm and this was used for the sensitive assay of the drug by Kalyanaramu and Raghubabu [34].

No titrimetric method was found in the literature for the quantification of STS in pharmaceuticals. The reported visible spectrophotometric methods suffer from one or more disadvantages such as rigid pH control, heating and/or extraction step, use of multi-step reaction/s, longer contact time, less stable colored species, narrow linear dynamic range etc as indicated in Table 1.

The present paper describes one titrimetric and one visible spectrophotometric methods based on the reduction of potassium permanganate (KMnO₄) in acid medium. Simplicity, sensitivity, wide linear ranges, mild

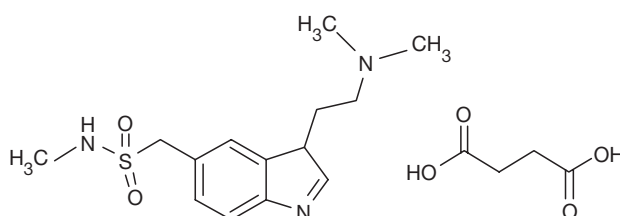


Figure 1 Structure of sumatriptan succinate

experimental conditions and above all cost-effectiveness characterize the proposed methods. Optimum conditions were established and both the methods were validated

according to ICH guidelines. The validated methods when applied to the determination of STS in tablets yielded results which were in good agreement with the label claim.

Table 1 Comparison of the proposed and the existing visible spectrophotometric methods

No.	Reagent/s	Methodology	λ_{max} , nm	Beer's law range, $\mu\text{g ml}^{-1}$ (ϵ in $\text{l mol}^{-1} \text{cm}^{-1}$)	Remarks	Ref
1	Bromate-bromide- a) methyl orange, b) indigo carmine	Unreacted bromine was measured	508 610	1.90×10^5 2.71×10^4	Multi step reaction, time consuming.	28
2	Folin-Ciocaltaeu reagent	Reduced FC-reagent was measured	760	-	-	22
3	a) Quinone b) acetaldehyde with <i>p</i> -chloranil	CT-complex measured	548 660	1.00×10^4 3.19×10^4	Involves heating step, time consuming.	29
4	Sodium nitroprusside acetaldehyde	Inner molecular complex formed was measured	552	1.10×10^4	Requires rigid pH control	30
5	a) Brucine-sodium metaperiodate, b) Citric acid-acetic anhydride	Oxidative coupling product was measured	520 580	- -	Multi-step reaction	31
6	Folin reagent	Chromogen formed by reaction with drug was measured	455.6	3.85×10^3	Strict pH control, time consuming.	32
7	Cobalt thiocyanate	Extracted ternary complex formed by reaction with drug was measured	629.4	3.97×10^3	Involves extraction step	33
8	Tropaeolin-OOO	Extracted ion-pair complex was measured.	482.5	2.08×10^4	Requires rigid pH control; involves liquid-liquid extraction; use of organic solvents.	34
9	<i>p</i> -Chloranilic acid	CT-complex measured	520	9.28×10^2	Less sensitive; use of organic solvents.	37
10	KMnO ₄	Unreacted KMnO ₄ measured	545	1.39×10^4	Very simple, no heating or extraction step, cost-effective, sensitive and free from any experimental variable.	Present method

Materials and Methods

Apparatus

Absorbance measurements were made with a Systronics model 106 digital spectrophotometer equipped with 1-cm matched quartz cells.

Reagents and standards

All chemicals used were of analytical grade and solutions were made in distilled water.

Potassium permanganate (0.01 M and 600 $\mu\text{g ml}^{-1}$)

An approximately 0.01 M solution was prepared by dissolving 395 mg of KMnO_4 (Merck, Mumbai, India) in water and diluting to 250 ml in a calibrated flask, and standardized using H.A. Bright's procedure [35]. The standard solution was used in method A and then diluted appropriately with water to get 600 $\mu\text{g ml}^{-1}$ working concentration for method B.

Ferrous ammonium sulphate (FAS)

A 0.05 M solution of FAS was prepared by dissolving 4.90 g of the salt (S.D. Fine Chem, Mumbai, India) in 50 ml of water containing 1 ml of concentrated H_2SO_4 , and diluted to 250 ml with water.

Sulphuric acid (5 M)

Concentrated acid (S.D. Fine Chem, Mumbai, India, sp. gr. 1.84) was appropriately diluted with water to get the required concentration.

Standard STS solution

Pharmaceutical grade STS certified to be 99.50% pure was kindly provided by MSN laboratories, Hyderabad, India; and was used as received. A 1 mg ml^{-1} stock standard solution was prepared by dissolving accurately weighed 250 mg of pure STS in water and diluting to the mark in a 250 ml calibrated flask and used in method A. It was subsequently diluted to 40 $\mu\text{g ml}^{-1}$ STS for the use in method B.

Tablets

Two brands of tablets claimed to contain 25 and 50 mg STS per tablet were purchased from local market for investigation.

Recommended procedures

Titrimetry (method A)

A 10.0 ml aliquot of pure drug solution containing

1.0-7.0 mg of STS was measured accurately and transferred into a 100 ml titration flask. The solution was acidified by adding 3 ml of 5M H_2SO_4 . Then, 10 ml of 0.01 M KMnO_4 was added by means of a pipette and the flask was let stand for 10 min at room temperature and unreacted KMnO_4 was titrated with 0.05 M FAS to a colorless end point. A blank experiment was simultaneously performed.

The amount of STS was computed from the following formula:

$$\text{Amount (mg)} = \frac{V_r \times M_r \times S}{n} \quad (1)$$

Where, M_r = relative molecular mass of drug, S = strength (M) of KMnO_4 , V_r = volume (ml) of KMnO_4 , n = number of moles of KMnO_4 reacting with per mole of STS = 6.

Spectrophotometry (method B)

Aliquots of standard STS solution (40 $\mu\text{g ml}^{-1}$) in the range 0.2-4.0 ml were accurately measured and transferred to a series of 10 ml calibrated flasks and the volume was adjusted to 4.0 ml with water. One ml of 5 M H_2SO_4 was added to each flask followed by 1 ml of 600 $\mu\text{g ml}^{-1}$ KMnO_4 solution. The content was mixed and the flasks were let stand for 15 min before diluting to the mark with water. The absorbance of each solution was measured at 545 nm against water.

Procedure for tablets

Twenty tablets were weighed accurately and pulverized. A quantity of the powder containing 100 mg of STS was accurately weighed into a 100 ml calibrated flask, added 60 ml of water and shaken for 20 min. Then, the volume was diluted to the mark with water, mixed and filtered using a Whatman No 42 filter paper. First 10 ml of the filtrate was discarded and a suitable aliquot was used in the assay of STS by method A. The filtrate (1000 $\mu\text{g ml}^{-1}$ in STS) was next diluted with water to obtain 40 $\mu\text{g ml}^{-1}$ solution for the use in method B and the analysis was completed using the procedure described earlier.

Procedure for placebo blank and synthetic mixture analyses

A placebo blank containing talc (25 mg), starch (30 mg), lactose (20 mg), calcium carbonate (20 mg), calcium dihydrogen orthophosphate (20 mg), methyl cellulose (40 mg), sodium alginate (70 mg) and magnesium stearate (10 mg) was prepared by mixing and 50 mg extracted with water and solution made as described under “procedure for tablets”. A convenient aliquot of solution was subjected to analysis by titrimetry (method A) and spectrophotometry (method B) according to the recommended procedures.

A synthetic mixture was prepared by adding 100 mg of STS to 100 mg of the placebo blank prepared above, homogenized and the solution was prepared as done under “procedure for tablets”. The filtrate was collected in a 100-ml flask and a 5 ml aliquot was assayed by method A. The synthetic mixture solution (1000 µg ml⁻¹ in STS) was appropriately diluted to get 40 µg ml⁻¹ solutions, and appropriate aliquot was subjected to analysis by method B.

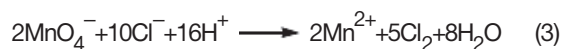
Results and Discussion

Potassium permanganate is a strong oxidizing agent and the salt is known as permanganate of potash and in this salt, manganese is in the +7 oxidation state. The innate intense purple color solution of permanganate absorbs in the vicinity of 545 nm. As a strong oxidant it does not generate toxic byproducts.

The Mn-containing products from redox reactions depend on the pH. In acid solutions, permanganate is reduced to the faintly pink Mn²⁺ as represented by the following equation:



The standard potential in acid solution, E, has been calculated to be 1.51 volts, hence the permanganate ion in acid solution is a strong oxidizing agent [36]. Sulphuric acid is the most suitable acid, as it has no action upon permanganate in dilute solution. With hydrochloric acid, there is the likelihood of the reaction: taking place and some permanganate may be consumed in the formation of chlorine [36].



The proposed titrimetric method is based on the oxidation of drug with known excess of KMnO₄ in acidic medium and unreacted KMnO₄ was determined by titrating it with 0.05 M FAS. The reaction stoichiometry was found to be 1:6 (STS: KMnO₄). Spectrophotometric method involves the addition of known excess of permanganate to STS in acidic medium followed by the determination of unreacted permanganate at 545 nm. The possible sequences of reactions are presented in Figure 2.

Optimization of variables

The experimental variables which provided accurate and precise results were optimized. The influence of each variable involved in the assays was examined.

Titrimetry (method A)

In titrimetry, the reaction was found to be stoichiometric in H₂SO₄ medium. The effect of acid concentration on the reaction between STS and KMnO₄ was studied by varying the concentration of H₂SO₄ while keeping the concentrations of KMnO₄ and

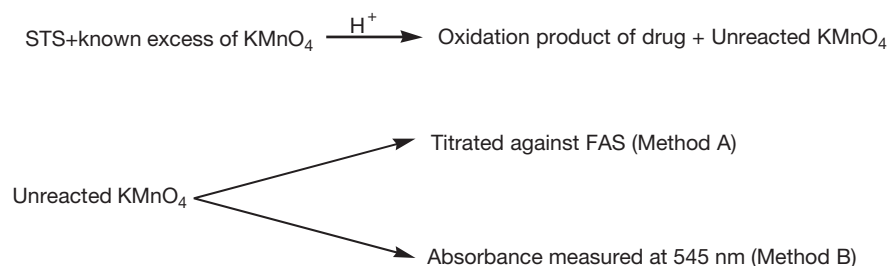
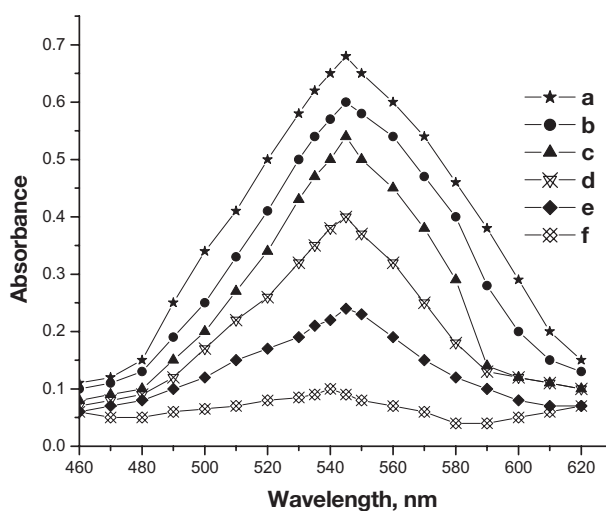


Figure 2 Possible sequences of reactions

Table 2 Regression and analytical parameters of spectrophotometric method

Parameter	Method B
λ_{max} , nm	545
Beer's law limits, $\mu\text{g ml}^{-1}$	0.8-16.0
Molar absorptivity (ϵ), $\text{l mol}^{-1} \text{cm}^{-1}$	1.39×10^4
Sandell sensitivity ^a , $\mu\text{g cm}^{-2}$	0.0298
Limit of detection (LOD), $\mu\text{g ml}^{-1}$	0.41
Limit of quantification (LOQ), $\mu\text{g ml}^{-1}$	1.23
Regression equation, Y^b	
Intercept, (a)	0.6924
Slope, (b)	-0.0382
Correlation coefficient (r)	0.9994
Standard deviation of intercept (S_a)	0.00584
Standard deviation of slope (S_b)	0.00065

^aLimit of determination as the weight in μg per mL of solution, which corresponds to an absorbance of $A = 0.001$ measured in a cuvette of cross-sectional area 1 cm^2 and $l = 1 \text{ cm}$. $Y^b = a + bX$, where Y is the absorbance, X is concentration in $\mu\text{g mL}^{-1}$, a is intercept, and b is slope.

**Figure 3** Absorption spectra of blank (a), 2 (b), 4 (c), 8 (d), 12 (e), and 16 (f) $\mu\text{g ml}^{-1}$ of sumatriptan succinate (STS), respectively

drug fixed. The reaction stoichiometry was unaffected when 0.454-1.67 M H_2SO_4 was maintained. Hence, 3 ml of 5 M H_2SO_4 in a total volume of 30 ml (1.15 M overall) was used. The reaction stoichiometry was calculated to be 1:6 (STS: KMnO_4) in the 1.0-7.0 mg range. Below and above these limits slightly irregular stoichiometries were obtained. The reaction between STS and KMnO_4 was found to be complete and quantitative in 10 min and contact time up to 30 min had no effect on the stoichiometry or the results.

Spectrophotometry (method B)

Absorption spectra

When a fixed concentration of KMnO_4 ($60 \mu\text{g ml}^{-1}$) was reacted with varying concentrations of STS, the former was consumed in proportion to STS concentration and there occurred a concomitant fall in the concentration of KMnO_4 as shown by the decreasing absorbance values at 545 nm with increase in the STS concentration. This is depicted in Figure 3. This facilitated the evaluation of the linear range over which the method is applicable to

the determination of STS. Preliminary experiments were performed to determine the concentration of KMnO_4 which gave maximum absorbance at 545 nm in the acid medium employed and this was found to be $60 \mu\text{g ml}^{-1}$.

Effect of H_2SO_4

To maintain the acidic condition, H_2SO_4 is used in this reaction. H_2SO_4 is the most suitable acid, as it has no action upon permanganate on dilution, and with hydrochloric acid, there is the likelihood of the formation of chlorine where some permanganate may be consumed. Hence, the reaction of the oxidant with the drug was carried out in H_2SO_4 medium. To investigate the effect of H_2SO_4 concentration on the reaction, 0.5-4.0 ml of 5 M H_2SO_4 was added to a fixed concentration of STS

($40 \mu\text{g ml}^{-1}$) and KMnO_4 ($60 \mu\text{g ml}^{-1}$), and it was observed that constant absorbance readings were obtained when 0.5-4.0 ml of 5 M H_2SO_4 in a total volume of 10 ml was used (Figure 4). Hence, 1 ml of 5 M H_2SO_4 was fixed as the optimum.

Reaction time

The reaction was found to be complete and quantitative when the reaction mixture was allowed to stand for 15 min, and beyond this standing time up to 45 min the absorbance remained constant (Figure 5). Hence, 15 min of reaction time was used in the assay.

Method validation procedures

The proposed methods have been validated for linearity, sensitivity, selectivity, precision, accuracy and recovery.

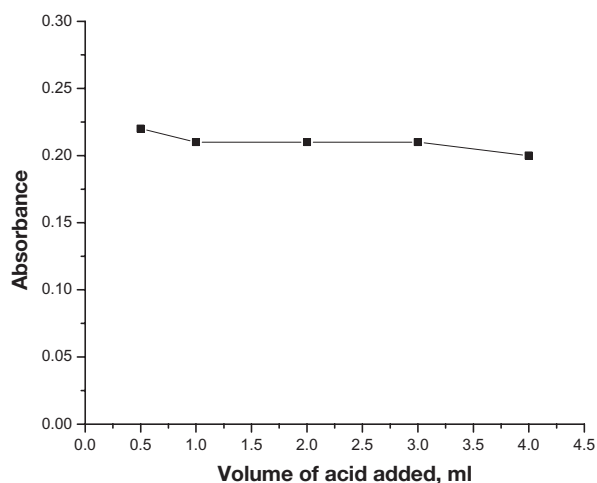


Figure 4 Effect of different volumes of 5 M H_2SO_4 in method B for determination of sumatriptan succinate (STS) $40 \mu\text{g ml}^{-1}$

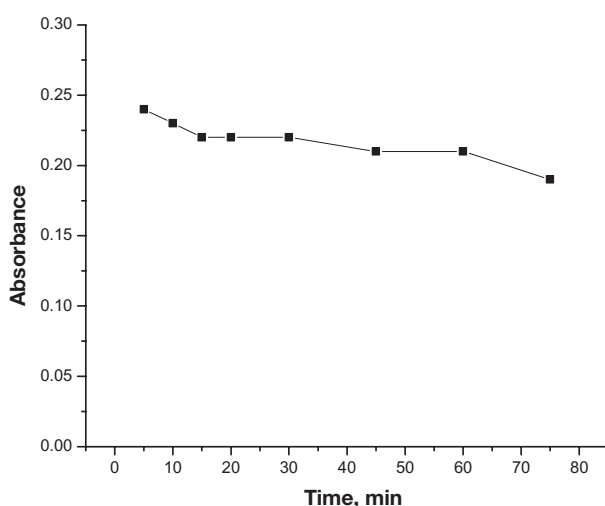


Figure 5 Effect of reaction time for determination of $40 \mu\text{g ml}^{-1}$ sumatriptan succinate (STS) in method B

Linearity and sensitivity

Over the range investigated (1-7 mg), a fixed stoichiometry of 1:6 (STS: KMnO_4) was obtained in titrimetry (method A), which served as the basis for calculations. In spectrophotometry, under optimum conditions a linear relation was obtained between absorbance and concentration of STS in the range of 0.8-16.0 $\mu\text{g ml}^{-1}$ (method B) and the Beer's law is obeyed in the inverse manner. The calibration graph is described by the equation:

$$Y = a + bX \quad (4)$$

(where Y = absorbance, a = intercept, b = slope and X = concentration in $\mu\text{g ml}^{-1}$) obtained by the method of least squares. Correlation coefficient, intercept and slope for the calibration data are summarized in Table 2. Sensitivity parameters such as apparent molar absorptivity and Sandell's sensitivity values, as well as the limits of detection and quantification, were calculated as per the current ICH guidelines [37] and compiled in Table 2. The results attest to the sensitivity of the proposed method. The limits of detection (LOD) and quantification (LOQ) were calculated according to the same guidelines using the formulae:

$$\text{LOD} = 3.3\sigma/s \text{ and } \text{LOQ} = 10\sigma/s \quad (5)$$

where, σ is the standard deviation of five reagent blank determinations, and s is the slope of the calibration curve.

Precision and accuracy

In order to evaluate the precision of the proposed methods, solutions containing three different amounts/concentrations of the STS were prepared and analyzed in five replicates. The analytical results obtained from this investigation are summarized in Table 3. The low values of the relative standard deviation (% R.S.D) and percentage relative error (% R.E) indicate the precision and accuracy of the proposed methods. The percentage relative error is calculated using the following equation:

$$\% \text{ R.E.} = \frac{\text{found-taken}}{\text{taken}} \times 100 \quad (6)$$

The assay procedure was repeated five times, and percentage relative standard deviation (% R.S.D) values were obtained within the same day to evaluate repeatability (intra-day precision), and over five different days to evaluate intermediate precision (inter-day precision).

Selectivity

The proposed methods were tested for selectivity by placebo blank and synthetic mixture analyses. A convenient aliquot of the placebo blank solution, prepared as described earlier, was subjected to analysis by titrimetry and spectrophotometry according to the recommended procedures. In both cases, there was no interference by the inactive ingredients present in the placebo mixture.

A separate experiment was performed with the synthetic mixture. The analysis of synthetic mixture

Table 3 Evaluation of intra-day and inter-day precision and accuracy

Method	STS* taken	Intra-day (n = 5)			Inter-day (n = 5)		
		STS found ^a	%RSD ^b	%RE ^c	STS found ^a	%RSD ^b	%RE ^c
Method A	2.00	2.02	1.07	1.21	2.04	1.62	2.00
	4.00	4.02	0.98	0.42	4.04	1.77	1.01
	6.00	6.06	1.48	0.95	6.06	1.66	1.08
Method B	4.00	3.97	1.57	0.66	3.96	2.30	1.06
	8.00	8.08	0.70	1.04	8.09	0.94	1.17
	12.00	11.81	1.09	1.55	11.80	1.19	1.62

*In method A, sumatriptan succinate (STS) taken/found are in mg and they are $\mu\text{g ml}^{-1}$ in method B.

^aMean value of five determinations; ^bRelative standard deviation (%); ^cRelative error (%).

solution prepared above yielded percent recoveries of 98.28 ± 1.72 , and 101.90 ± 2.47 for titrimetry and spectrophotometry, respectively. The results of this study indicate that the inactive ingredients present in the synthetic mixture did not interfere in the assay. These results further demonstrate the accuracy, as well as the precision, of the proposed methods.

Robustness and ruggedness

To evaluate the robustness of the methods, volume of H_2SO_4 (3 ± 0.5 ml) and contact time (10 ± 1 min) were slightly altered with reference to optimum values in titrimetry. However, in spectrophotometry, the reaction time (after adding $KMnO_4$, time varied was 15 ± 1 min) and volume of H_2SO_4 were slightly altered (1 ± 0.1 ml). To check the ruggedness, analysis was performed by four different analysts in all the three methods.

The robustness and the ruggedness were checked at three different drug levels (2, 4, 6 mg in method A and 4, 8, 12 $\mu g\ ml^{-1}$ in method B). The intermediate precision, expressed as percent RSD, which is a measure of robustness and ruggedness, was within the acceptable limits (0.71-2.00%) as shown in Table 4.

Application to tablets

In order to evaluate the analytical applicability of the proposed methods to the quantification of STS in commercial tablets, the results obtained by the proposed methods were compared to those of the reference published method [12] by applying Student's *t*-test for accuracy and the *F*-test for precision. The published reference method describes UV-spectrophotometric method for detection of STS in tablet formulation at 220 nm. The results (Table 5) show that the Student's

Table 4 Robustness and ruggedness

STS studied (mg)	Method A			Method B			
	Robustness (RSD, %)		Ruggedness (RSD, %)	STS studies, $\mu g\ ml^{-1}$	Robustness (RSD, %)		Ruggedness (RSD, %)
	Conditions altered				Conditions altered		
	Volume of $H_2SO_4^a$ (n=3)	Reaction time ^b (n=3)	Inter-burettes (n=4)		Volume of $H_2SO_4^c$ (n=3)	Reaction time ^d (n=3)	Inter-cuvettes (n=3)
2.0	1.03	0.93	1.17	4.0	1.36	1.22	1.86
4.0	1.24	1.07	0.90	8.0	0.87	1.93	2.00
6.0	1.45	1.21	0.71	12.0	1.40	1.17	1.59

^aIn method A, volumes of 5 M H_2SO_4 varied were 3 ± 1 ml, ^bthe reaction time employed was 10 ± 1 min. ^cIn method B, volumes of 5 M H_2SO_4 varied were 1 ± 0.1 ml, ^dthe reaction time employed was 15 ± 1 min.

Table 5 Results of analysis of tablets by the proposed methods

Tablet brand name	Label claimed, mg/tablet	Found (Percent of label claimed \pm SD) ^a		
		Reference method [12]	Proposed methods	
			Method A	Method B
Suminat [®] -25	25	99.78 \pm 0.89	101.40 \pm 1.23	98.96 \pm 1.37
			<i>t</i> = 2.39 <i>F</i> = 1.91	<i>t</i> = 1.12 <i>F</i> = 2.37
Suminat [®] -50	50	100.60 \pm 1.01	101.80 \pm 0.91	99.12 \pm 1.65
			<i>t</i> = 1.97 <i>F</i> = 0.81	<i>t</i> = 1.71 <i>F</i> = 2.67

^aMean value of five determinations.

Tabulated *t*-value at the 95% confidence level is 2.78.

Tabulated *F*-value at the 95% confidence level is 6.39.

Table 6 Results of recovery study by standard addition method

Tablets studied	Method A				Method B			
	STS in tablets, mg ml ⁻¹	Pure STS added, mg ml ⁻¹	Total found, mg ml ⁻¹	Pure STS recovered*, Percent ± SD	STS in tablets, µg ml ⁻¹	Pure STS added, µg ml ⁻¹	Total found, µg ml ⁻¹	Pure STS recovered*, Percent ± SD
	Suminat [®] -25	2.03	1.0	3.04	101.00 ± 0.03	3.96	2.0	6.01
	2.03	2.0	4.06	101.50 ± 0.04	3.96	4.0	8.03	101.80 ± 0.69
	2.03	3.0	5.07	101.30 ± 0.02	3.96	9.9	9.93	99.50 ± 1.03
Suminat [®] -50	2.04	1.0	3.05	101.00 ± 0.05	3.96	2.0	6.00	102.00 ± 0.95
	2.04	2.0	4.02	99.00 ± 0.06	3.96	4.0	7.91	98.75 ± 1.06
	2.04	3.0	5.09	101.70 ± 0.03	3.96	6.0	10.08	102.00 ± 0.80

*Mean value of three determinations.

t- and *F*-values at a 95% confidence level are lower than the tabulated values, thereby confirming good agreement between the results obtained by the proposed methods and the reference method, with respect to accuracy and precision.

Recovery studies

The accuracy and validity of the proposed methods were further ascertained by performing recovery studies. Pre-analysed tablet powder was spiked with pure STS at three concentration levels (50, 100 and 150% of that in tablet powder) and the total was then determined by the proposed methods. In both the cases, the added STS recovery percentage values ranged from 98.75-102.5% with a standard deviation of 0.02-2.51 (Table 6), indicating good recovery and absence of interference from the co-formulated substances in the assay.

Conclusion

The proposed methods are free from rigid experimental conditions such as rigid pH control, liquid-liquid extraction, etc., and are characterized by simplicity and high sensitivity. These methods employ inexpensive and easily available chemicals and hence cost-effective when compared to the existing spectrophotometric methods. In addition, the methods have a high tolerance limit for common excipients found in drug formulations. The proposed methods are accurate and precise as indicated by good recoveries of the drugs and low

RSD values. The proposed methods can be applied for routine analysis and in quality control laboratories for quantitative determination of the drug both in the pure and dosage forms

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