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Spectrophotometric analysis of empagliflozin tablets as SGLT2 inhibitors in pharmaceutical samples

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ABSTRACT

Azo dyes account for 70% of dye chemistry, and their importance may grow in the future. Empagliflozin is a sodium-glucose co-transporter-2 (SGLT2) inhibitor. SGLT2 transporters are primarily responsible for glucose reabsorption in the kidney. In 2014, empagliflozin was approved for medical use in the United States and the European Union. With over 4 million prescriptions in 2019, it was the 146th most commonly prescribed medication in the United States in 2019. The spectrophotometric determination of empagliflozin is described using coupling agents such as 3-chloro-4-nitroaniline or sulfanilamide. These methods are straightforward and are based on the reaction of empagliflozin with diazotized products of 3-chloro-4-nitroaniline or sulfanilamide to produce colored azo dyes with absorption maxima at 470 and 480 nm. Empagliflozin was linear from 1.2 to 26.6 μgml^{-1} or 0.8 to 20.4 μgml^{-1} when combined with diazotized 3-chloro-4-nitroaniline or sulfanilamide, respectively. Empagliflozin's molar absorptivity and Sandell's sensitivity to 3-chloro-4-nitroaniline or sulfanilamide azo dyes were 3.179×10^4 l $mol^{-1}cm^{-1}$ or 4.367×10^4 l $mol^{-1}cm^{-1}$ and 1.149×10^{-2} μgcm^{-2} or 8.368×10^{-3} μgcm^{-2}, respectively. The formed colored azo dyes are stable for more than 12 hours. The optimal reaction conditions and other analytical parameters are assessed. Foreign organic compound interference has been studied. The method has been successfully used to determine empagliflozin in pharmaceutical samples.

INTRODUCTION

Azo dyes constitute 70% of dye chemistry, and their relative significance may increase in the future (Alsoghier *et al*., 2021; Benkhaya *et al*., 2020; Chen *et al*., 2021; Gester *et al*., 2020; Ben Mohamed-Smati *et al*., 2021; Omar *et al*., 2021; Prashantha *et al*., 2021; Rashidnejad *et al*., 2021; Selvaraj *et al*., 2021; Srinivasan and Sadasivam, 2021; Sweidan *et al*., 2018; Weldegebrieal, 2020).

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Empagliflozin (Fig. 1) is a competitive inhibitor of sodium-glucose co-transporter-2 that is orally active and has an antihyperglycemic effect (Hailat *et al*., 2022). It is approved for treating adults with type 2 diabetes in the EU, USA, and Japan, among other parts of the world (Frampton, 2018). This mechanism is independent of β-cell function; thus, these agents effectively treat type 2 diabetes mellitus at any disease stage (Levine, 2016; Mula-Abed and Aughsteen, 2005). Many methods have been adopted to determine empagliflozin (Ahmad *et al*., 2021). The liquid chromatography-mass spectrometry method was developed, optimized, and validated for simultaneous quantification of empagliflozin and metformin in human plasma using empagliflozin D4 and metformin D6 as an internal standard (Wattamwar *et al*., 2020). An Liquid Chromatography with tandem mass spectrometry (LC-MS-MS) method was developed

to determine empagliflozin and metformin using a bridged ethylene hybrid C18 column (Ayoub and Mowaka, 2017). Another univariate spectrophotometric method and multivariate chemometric approach were developed and compared to determine empagliflozin simultaneously and metformin manipulating their zero-order absorption spectra with application to their pharmaceutical preparation (Mabrouk *et al*., 2019). 4-Nitroaniline forms molecular adducts with 4-aminobenzoic acid. It reacts with nitrite ion in a hydrochloric acid medium to form 4-nitrophenyldiazonium chloride, which couples with naphth-1-ol in an alkaline medium to give a purple azo dye. (Figure 2) Photocatalytic degradation of 4-nitroaniline in the presence of TiO_2 suspensions in a batch and continuous annular reactor has been studied (Abed-Elmageed *et al*., 2020; Ayoub *et al*., 2021; Baveja *et al*., 1981; Marchewka *et al*., 2011; Wu *et al*., 2012). Sulfanilamide is an organic sulfur compound similar to *p*-aminobenzoic acid (PABA) with antibacterial properties. Sulfanilamide competes with PABA for the bacterial enzyme dihydropteroate synthase, thereby preventing the incorporation of PABA into dihydrofolic acid, the immediate precursor of folic acid (Dionisio *et al*., 2018; United States Pharmacopeial Convention, 2007).

Effect of acid, base concentration, and temperature used

The effect of acid and base on the diazotization reaction of empagliflozin (2 μgml^{-1}) was studied by adding different acidic solutions (1 M) such as HCl, HNO_3, H_2SO_4, and CH_3COOH and basic solutions (1 M) such as KOH, NaOH, Na_2CO_3, and NH_4OH. It was observed that CH_3COOH gave low absorbance with low color stability. In contrast, HCl gave high absorbance with the highest color stability, whereas 1.0 ml of NaOH gave the maximum absorbance for the reaction of empagliflozin coupled with diazotized 3-chloro-4-nitroaniline or sulfanilamide. Therefore, 0.5 ml of 0.5 M HCl (Table 1) and 1.0 ml of 1 M NaOH solutions were preferred for the diazotization reaction of empagliflozin.

The effect of various acids such as HCl, HNO_3, H_2SO_4, and CH_3COOH (0.5 M) on the diazotization reaction was studied under the maximum absorbance by varying the volume of different acids between 0.25 and 1.0 ml while fixing all other parameters. It was found that 0.5 ml of HCl (0.5 M) gave the highest absorbance and was preferred for the diazotization reaction of empagliflozin (Table 2).

Room temperature (25°C ± 5°C) is recommended for these diazotization reactions because losses in color intensity and stability were observed at low or high temperature.

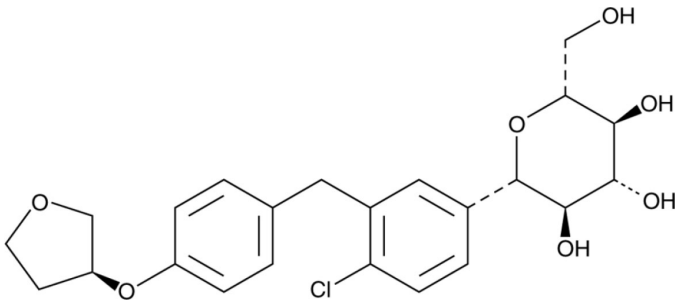


Figure 1. Empagliflozin structure.

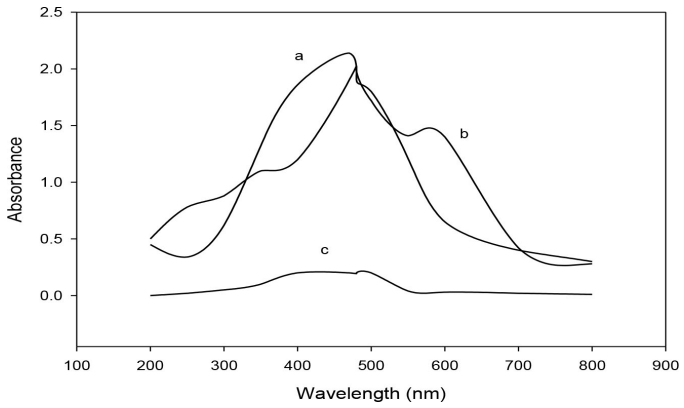


Figure 2. Absorption spectra of the diazo-couple of nitrite with 3-chloro-4-nitroaniline against reagent blank (a), absorption spectra of the diazo-couple of nitrite with sulfanilamide against reagent blank (b), and reagent blank against double-distilled water (c).

Effect of nitrite concentration and coupling reagents

The color is at maximum intensity when using 1 ml of a 0.1 M sodium nitrite solution using the current procedure with 2 μgml^{-1} of empagliflozin and adding 1 ml of 0.02–0.16 M solutions of the nitrite in hydrochloric acid (0.5 M) to a series of nitrite solutions. A higher concentration did not build up the absorbance further, and at a lower concentration, no good results were obtained (Table 3).

The current procedure uses 3-chloro-4-nitroaniline or sulfanilamide as a coupling agent by taking 2 μgml^{-1} of empagliflozin and adding 0.25–2.0 ml of 1% 3-chloro-4-nitroaniline or sulfanilamide to a string of nitrite solutions. The

Table 1. Acid concentration on absorbance.

0.5 ml HCl used (M)	Absorbance (A)	
	3-Chloro-4-nitroaniline	Sulfanilamide
0.1	0.296	0.315
0.2	0.346	0.345
0.3	0.368	0.386
0.4	0.388	0.398
0.5	0.450	0.422
0.6	0.416	0.384

Table 2. Different acid concentrations on absorbance.

0.5 M acid concentration used	Absorbance (A)/ml of acid used			
	0.25 ml	0.5 ml	0.75 ml	1.0 ml
Acetic acid	0.206	0.222	0.212	0.198
Sulfuric acid	0.246	0.322	0.306	0.294
Nitric acid	0.254	0.304	0.293	0.286
Hydrochloric acid	0.262	0.364	0.348	0.312

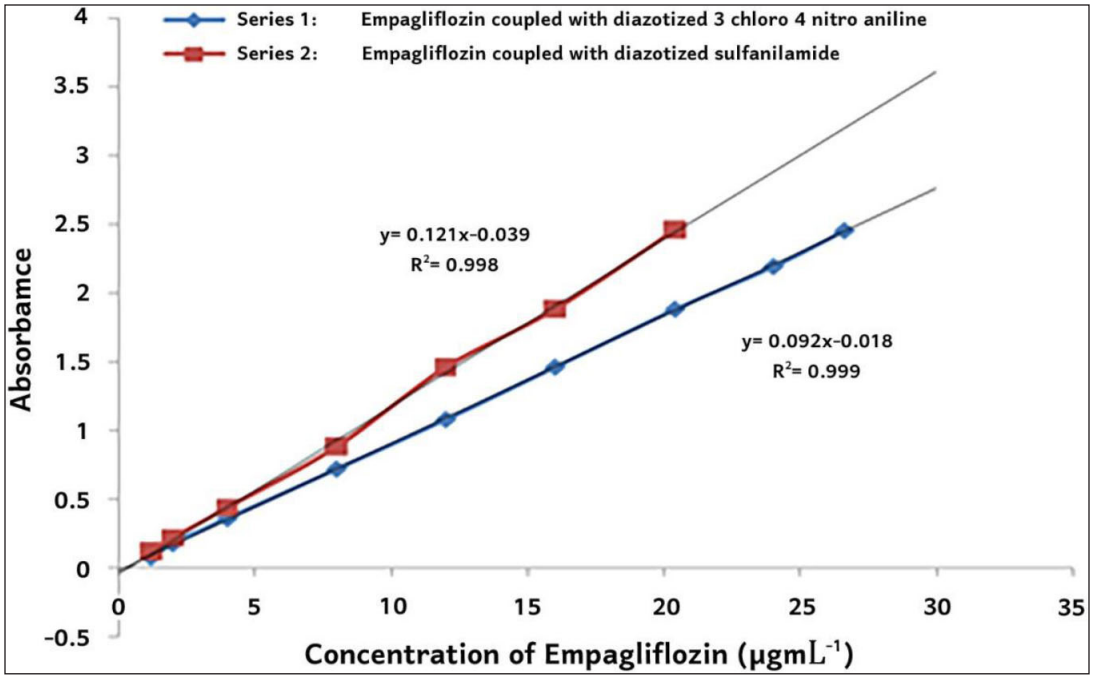


Figure 3. Adherence to Beer's law using empagliflozin coupled with diazotized 3-chloro-4-nitroaniline and sulfanilamide.

Table 3. Effect of $NaNO_2$ on absorbance.

1 ml of $NaNO_2$ solution used (M)	Absorbance (A)	1 ml of $NaNO_2$ solution used (M)	Absorbance (A)
0.02	0.188	0.10	0.353
0.04	0.208	0.12	0.326
0.06	0.264	0.14	0.315
0.08	0.287	0.16	0.314

firmest color was obtained with 1 ml of a 3-chloro-4-nitroaniline or sulfanilamide (1%) solution in 10.0 ml (Table 4).

Effect of interference

Some excipients generally present in the pharmaceutical preparations were examined by carrying out the determination of empagliflozin in the presence of different excipients such as glucose (1,200 μgml^{-1}), fructose (1,000 μgml^{-1}), lactose (800 μgml^{-1}), starch (600 μgml^{-1}), and urea (300 μgml^{-1}), which did not interfere.

Analytical data

A straight line is obtained in the graph by plotting absorbance beside the concentration of empagliflozin. (Figure 3) Beer's law is obeyed in the range of 1.2–26.6 μgml^{-1} of empagliflozin with 3-chloro-4-nitroaniline or 0.8–20.4 μgml^{-1} of empagliflozin with sulfanilamide (Figure 3). The molar absorptivity of the colored azo dye of empagliflozin coupled with diazonium salt 3-chloro-4-nitroaniline or sulfanilamide was Scheme 1 and 2 3.179×10^4 l $mol^{-1}cm^{-1}$ or 4.367×10^4 l $mol^{-1}cm^{-1}$ (Figure 3). On the other hand, Sandell's sensitivity to the colored system with nitrite-3-chloro-4-nitroaniline or nitrite-sulfanilamide was found to be 1.149×10^{-2} μgcm^{-2} or 8.368×10^{-3} μgcm^{-2}, respectively.

The detection limit ($D_L = 3.3\ \sigma/S$) and quantitation limit ($Q_L = 10\ \sigma/S$) of empagliflozin coupled with diazotized 3-chloro-4-nitroaniline or sulfanilamide were found to be 0.363 and 1.100 μgml^{-1} or 0.270 and 0.820 μgml^{-1} [where σ is standard deviation ($n = 5$) and S is slope of the curve] and the correlation coefficient of empagliflozin with 3-chloro-4-nitroaniline or empagliflozin with sulfanilamide was 0.999 or 0.998. The better optical characteristics and statistical data were obtained under optimum conditions (Table 5).

Applications

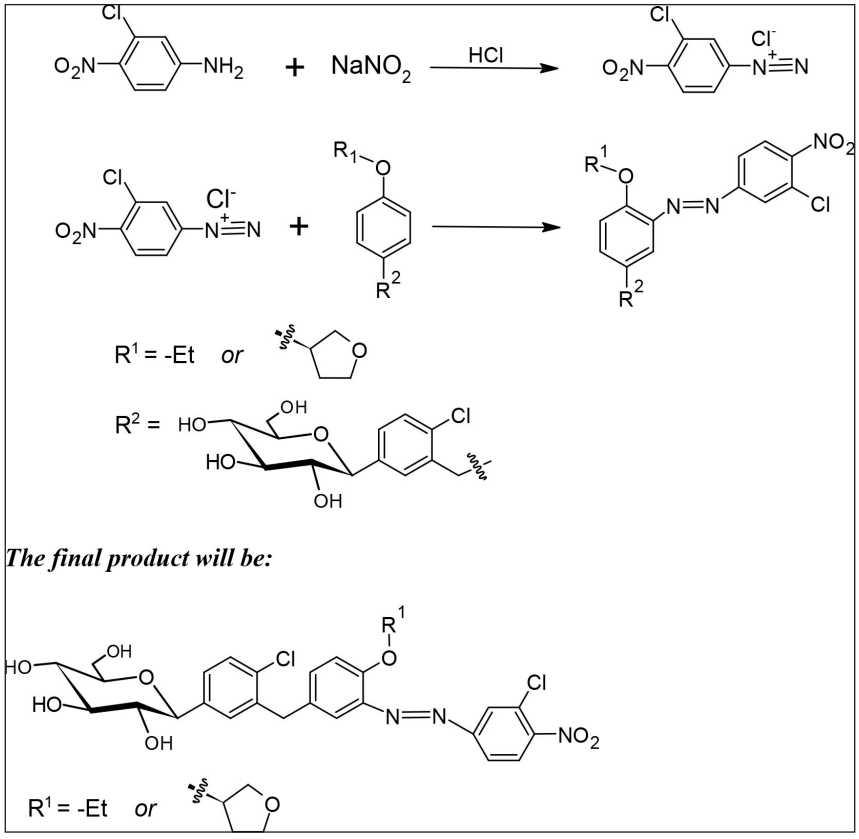
This simple and uncomplicated method is beneficial for determining empagliflozin in different pharmaceutical samples. The results of the offered method are in good agreement with the acknowledged content. The relative standard deviation and percentage recoveries for all five samples ranged from 0.81% to 2.27% and 98.00% to 100.40% at 95% confidence. The additional ingredients present in pharmaceutical sample appearances did form, not hinder. The results (Table 6) are compared with the endorsed spectrophotometric method (Ayoub, 2016; Patil *et al*., 2017). These confirm no significant differences between

Table 4. Effect of 3-chloro-4-nitroaniline or sulfanilamide solution on absorbance.

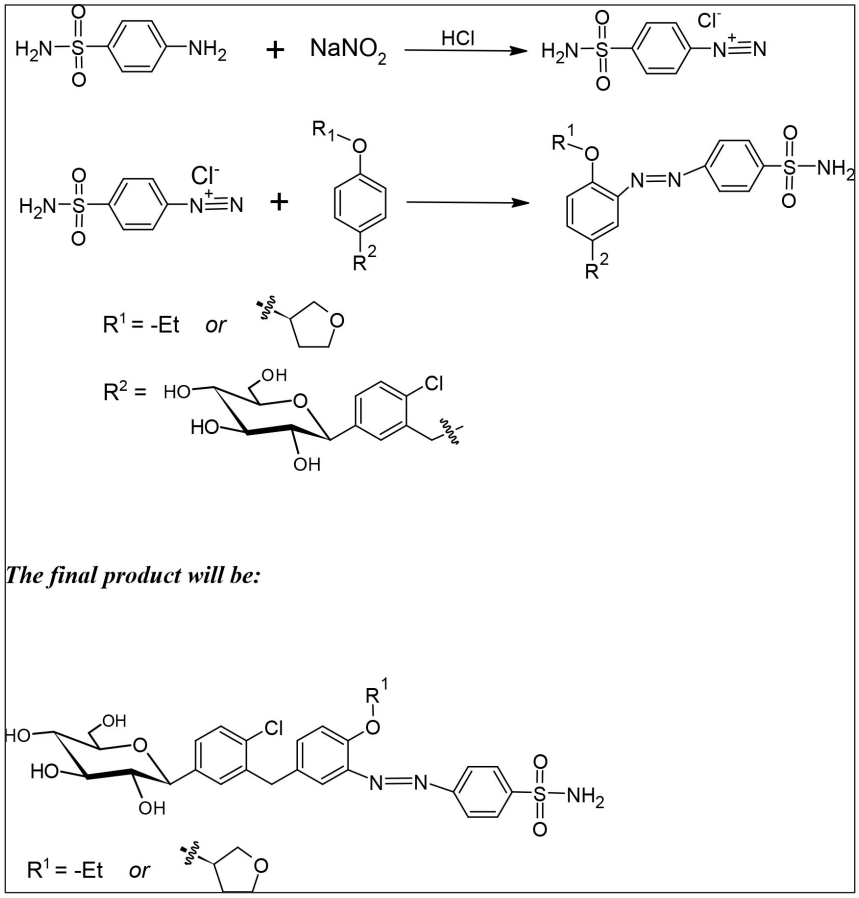
1% 3-chloro-4-nitroaniline or sulfanilamide solution used (ml)	Absorbance (A) for 3-chloro-4-nitroaniline	Absorbance (A) for sulfanilamide
0.25	0.298	0.258
0.50	0.304	0.264
0.75	0.321	0.303
1.00	0.344	0.312
1.25	0.331	0.306
1.50	0.328	0.300
1.75	0.325	0.287
2.00	0.326	0.281

Table 5. Optical characteristics and statistical data.

Parameter	Values obtained when 3-chloro-4-nitroaniline used	Values obtained when sulfanilamide used
Molar absorptivity	3.179×10^4 l mol^{-1}cm^{-1}	4.367×10^4 l mol^{-1}cm^{-1}
Shandell's sensitivity	1.149×10^{-2} µgcm^{-2}	8.368×10^{-3} µgcm^{-2}
Detection limit	0.363 µgml^{-1}	1.100 µgml^{-1}
Quantitation limit	0.270 µgml^{-1}	0.820 µgml^{-1}
Linearity range (µgml^{-1})	1.2–26.6 µgml^{-1}	0.8–20.4 gml^{-1}
Regression equation	$y = 0.092x - 0.018$	$y = 0.121x - 0.039$
Calibration sensitivity	0.092	0.121
Correlation coefficient (R^2)	0.999	0.998
Color stability	12 hours	12 hours
λ_{max} (nm)	470	480



Scheme 1. Formation of colored azo dye.



Scheme 2. Formation of colored azo dye.

Table 6. Determination of empagliflozin in different pharmaceutical samples using 3-chloro-4-nitroaniline or sulfanilamide as a coupling agent for three trade names of empagliflozin.

Pharmaceutical samples	Sample taken (μgml^{-1})	Using 3-chloro-4-nitroaniline		Using sulfanilamide	
		Sample found (μgml^{-1}) ± SD ± RSD	Rec. (%)	Sample found [a] (μgml^{-1}) ± SD ± RSD	Rec. (%)
Jardiance 25 (25 mg/tab.), Boehringer Ingelheim International GmbH, Germany	5.000	4.90 ± 0.08 ± 1.63	98.00	4.96 ± 0.06 ± 1.21	99.20
	10.000	9.91 ± 0.12 ± 1.21	99.10	10.00 ± 0.10 ± 1.00	100.0
	15.000	14.94 ± 0.18 ± 1.20	99.60	14.96 ± 0.28 ± 1.87	99.73
	20.000	19.92 ± 0.25 ± 1.25	99.60	19.96 ± 0.35 ± 1.75	99.80
Empagliflozin tab. (25 mg/tab.), Cipla Ltd, India	5.0	4.96 ± 0.06 ± 1.20	99.20	4.98 ± 0.10 ± 2.00	99.60
	10.0	9.94 ± 0.12 ± 1.21	99.40	9.94 ± 0.16 ± 1.61	99.40
	15.0	14.92 ± 0.20 ± 1.34	99.40	14.94 ± 0.24 ± 1.60	99.60
	20.0	19.91 ± 0.38 ± 1.91	99.50	19.92 ± 0.30 ± 1.50	99.60
Emjard 25 (25 mg/tab.), Square Centre, Bangladesh	5.0	4.92 ± 0.04 ± 0.81	98.40	5.02 ± 0.06 ± 1.19	100.40
	10.0	9.93 ± 0.14 ± 1.41	99.30	9.95 ± 0.18 ± 1.81	99.50
	15.0	14.95 ± 0.16 ± 1.07	99.70	14.91 ± 0.28 ± 1.87	99.40
	20.0	19.92 ± 0.36 ± 1.81	99.66	19.90 ± 0.42 ± 2.11	99.50

[a] Mean (n = 5) ± SD (standard deviation) ± RSD (relative standard deviation).

the offered and endorsed methods. The precision and accuracy were evaluated by replicate analysis of three different samples containing empagliflozin at different concentrations.

CONCLUSION

Sulfanilamide and 3-chloro-4-nitroaniline, the first spectrophotometric coupling agents used to determine empagliflozin, are inexpensive and equitably selective. Compared to other methods, this one is simple, quick, sensitive, and reproducible, has good precision and accuracy, and has high dye stability (12 hours).

As low relative standard deviation and percentage recovery values highlighted good accuracy and precision of the proposed methods, no tedious separation or solvent extraction procedures were required. There is no interference from excipients in results obtained using the proposed methods. The proposed method examined empagliflozin levels in pharmaceutical samples, which can be applied to more complex samples. For example, a blood sample to determine the blood level of empagliflozin helps in various pharmacokinetic and toxicological studies.

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AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the international committee of medical journal editors (ICMJE) requirements/guidelines.

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The authors report no financial or any other conflicts of interest in this work.

ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

DATA AVAILABILITY

All data generated and analyzed are included within this research article.

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