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Pankaj Chaudhari[1], Dr. Priyanka Patil[2], Dr. Chainesh Shah[3], Dr. Umesh Upadhyay[4]

[1]Research Scholar, [2]Director, [3]Research Coordinator & Professor, [4]The Dean
Faculty of Pharmacy, Sigma University, Vadodara – 390019, Gujrat, India

REVIEW OF CHROMATOGRAPHIC AND SPECTROPHOTOMETRIC METHODS FOR DAPAGLIFLOZIN ESTIMATION IN BULK AND FORMULATIONS

Pankaj Chaudhari[1]*, Dr. Priyanka Patil[2], Dr. Chainesh Shah[3], Dr. Umesh Upadhyay[4]
[1]Research Scholar, [2]Director, [3]Research Coordinator & Professor, [4]The Dean
Faculty of Pharmacy, Sigma University, Vadodara – 390019, Gujrat, India

Corresponding Author: pankajchaudhari1612@gmail.com

ABSTRACT: Dapagliflozin, a sodium-glucose cotransporter-2 (SGLT2) inhibitor, is widely used in the management of type 2 diabetes mellitus due to its ability to promote glucose excretion via urine. The accurate estimation of dapagliflozin, both as a single drug and in combination with other antidiabetic agents, is essential for ensuring drug quality, efficacy, and regulatory compliance. Various analytical techniques, such as UV spectrophotometry, High-Performance Liquid Chromatography (HPLC), and High-Performance Thin-Layer Chromatography (HPTLC), have been employed for its quantification in bulk drugs and pharmaceutical formulations. UV spectrophotometry offers a simple, cost-effective, and rapid method for routine estimation, especially in single-component formulations. HPLC, on the other hand, provides high sensitivity, precision, and the ability to separate dapagliflozin from impurities or other co-administered drugs in complex matrices, making it the method of choice for stability studies and quality control. HPTLC offers a flexible and efficient technique for high-throughput analysis, allowing the simultaneous quantification of multiple drugs in combination formulations. This review highlights the development, validation, and comparative analysis of these techniques, focusing on their respective advantages, limitations, and applicability for the accurate quantification of dapagliflozin in pharmaceutical and biological samples.

KEYWORDS: Dapagliflozin, Analytical Method, HPLC Method, HPTLC Method, UV Spectrophotometry Method

Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by elevated blood glucose levels due to the body's inability to produce sufficient insulin or to effectively use the insulin it produces. There are two main types of diabetes: type 1, which is insulin-dependent, and type 2, which is associated with insulin resistance and accounts for approximately 90% of all diabetes cases worldwide. Uncontrolled diabetes can lead to severe complications such as cardiovascular disease, kidney failure, neuropathy, and retinopathy. Proper management of blood glucose levels through lifestyle modifications, medications, and insulin therapy is

essential to preventing these complications. The global prevalence of diabetes continues to rise, making it a significant public health challenge that requires effective treatment strategies and innovative therapeutic approaches (Shah et al. 2024; Galicia-Garcia et al. 2020; Sapra and Bhandari 2021).

Dapagliflozin, a sodium-glucose cotransporter-2 (SGLT2) inhibitor, has gained prominence in the management of type 2 diabetes mellitus by promoting glucose excretion through urine. Dapagliflozin is used in the treatment of type 2 diabetes because it helps lower blood glucose levels by inhibiting the sodium-glucose cotransporter-2 (SGLT2) in the kidneys, promoting glucose excretion through urine (Anderson 2014). This mechanism allows for insulin-independent glucose control, which is particularly beneficial for patients with insulin resistance. Additionally, dapagliflozin provides cardiovascular and renal protective effects, making it a valuable option for patients with comorbid conditions such as heart failure and chronic kidney disease. As its therapeutic use expands, there is a growing need for accurate, reliable, and efficient methods to estimate dapagliflozin in both bulk drug substances and pharmaceutical formulations. Precise quantification is critical for ensuring drug quality, efficacy, and compliance with regulatory standards (Suthar et al. 2018; A. K. Sen et al. 2024).

Chromatographic and spectrophotometric techniques are among the most commonly employed analytical methods for dapagliflozin estimation. High-Performance Liquid Chromatography (HPLC) is widely recognized for its high sensitivity, precision, and ability to separate drug compounds from impurities (Nikolin et al. 2004). HPLC is extensively used in quality control, stability studies, and dissolution testing. Alongside HPLC, spectrophotometric methods, particularly UV-visible spectroscopy, offer a cost-effective and straightforward approach for routine estimation, particularly when advanced instrumentation is unavailable (Anon. 2024a; Nikolin et al. 2004). High-Performance Thin-Layer Chromatography (HPTLC) provides additional flexibility by allowing the simultaneous analysis of multiple samples, which is particularly useful in high-throughput settings (Attimarad et al. 2011).

This review presents an in-depth evaluation of the chromatographic and spectrophotometric methods developed for dapagliflozin estimation. By comparing various approaches, it aims to provide insights into method selection and optimization for researchers and quality control laboratories, ensuring accurate and reproducible dapagliflozin quantification.

Mechanism of Action

Dapagliflozin exerts its pharmacological effect by selectively inhibiting the sodium-glucose cotransporter-2 (SGLT2) in the proximal tubules of the kidneys. SGLT2 is responsible for approximately 90% of glucose reabsorption in the kidneys. By blocking this transporter,

dapagliflozin promotes glucose excretion through urine, reducing blood glucose levels independent of insulin action. This mechanism is particularly advantageous for type 2 diabetes patients, as it reduces hyperglycemia without directly affecting insulin secretion or sensitivity. In addition to glucose excretion, dapagliflozin also induces mild diuresis due to its osmotic effects, leading to reduced blood pressure, which is beneficial for patients with comorbid hypertension (Anderson 2014; Anon. 2024b).

Pharmacological Use

Dapagliflozin is primarily indicated for the treatment of type 2 diabetes mellitus. It is often prescribed as a monotherapy or in combination with other antidiabetic agents such as metformin, sulfonylureas, or insulin. Beyond glycemic control, dapagliflozin has demonstrated cardiovascular and renal protective effects, making it a valuable therapeutic option for patients with heart failure and chronic kidney disease, regardless of diabetes status. Studies have shown that dapagliflozin reduces the risk of hospitalization for heart failure and delays the progression of kidney disease, thereby expanding its therapeutic applications (Anderson 2014; Anon. 2024b).

Adverse Effects

While dapagliflozin is generally well-tolerated, it is associated with certain adverse effects that must be carefully monitored. The most common side effects include urinary tract infections (UTIs) and genital mycotic infections, both of which are related to the increased glucose concentration in the urine. Patients may also experience polyuria, which can lead to dehydration or volume depletion, particularly in older adults. Rare but serious adverse effects include diabetic ketoacidosis (DKA), which can occur even with normal blood glucose levels, and acute kidney injury, particularly in patients with preexisting renal impairment. Dapagliflozin has also been associated with a slight increase in the risk of bone fractures and amputations, although the exact mechanisms remain unclear (Anderson 2014; Anon. 2024b).

In summary, dapagliflozin offers significant benefits for glycemic control, cardiovascular protection, and renal preservation. However, careful consideration of its adverse effects is necessary for safe and effective use in clinical practice.

Physicochemical Parameters of Dapagliflozin (Anderson 2014; Anon. 2024b)

Dapagliflozin is an SGLT2 inhibitor, with the following key physicochemical characteristics:

- **Molecular Formula:** C21H25ClO6
- **Molecular Weight:** 408.88 g/mol
- **Physical State:** It appears as a white to off-white crystalline powder.
- **Melting Point:** Dapagliflozin has a melting point of approximately 85-90°C.

- **pKa:** The pKa of dapagliflozin is around 12.4, indicating it is weakly acidic.
- **Partition Coefficient (Log P):** Dapagliflozin has a Log P value of 1.8, suggesting moderate lipophilicity, allowing it to penetrate biological membranes.
- **Stability:** It is stable under normal storage conditions but can degrade under high temperature, light, and extreme pH conditions, which must be considered during formulation and storage.

These physicochemical properties are essential for understanding the drug's behavior in different pharmaceutical formulations, influencing its bioavailability, stability, and solubility.

Solubility of Dapagliflozin (Anon. 2024b; Anon. 2024c)

Solubility plays a significant role in the drug's absorption and bioavailability. Dapagliflozin exhibits the following solubility characteristics:

- **Water Solubility:** Dapagliflozin is sparingly soluble in water, which affects its formulation in aqueous-based dosage forms. To enhance its solubility, organic solvents or solubility enhancers are often employed.
- **Organic Solvent Solubility:** It is soluble in organic solvents like methanol, ethanol, and dimethyl sulfoxide (DMSO), which are commonly used during sample preparation for analytical methods.
- **pH-Dependent Solubility:** Dapagliflozin shows improved solubility in acidic environments, making it more soluble in gastric fluids, which facilitates absorption in the gastrointestinal tract.

Optimizing the solubility of dapagliflozin is critical for ensuring its therapeutic efficacy, especially in formulations like tablets and capsules.

Sample Preparation Strategies

The preparation of dapagliflozin samples from different matrices, such as bulk drug, pharmaceutical dosage forms, and biological fluids, is essential for accurate quantification in analytical methods like HPLC, HPTLC, and spectrophotometry. Below are the typical strategies employed:

1. Sample Preparation from Drug and Dosage Forms (Kuoni et al. 2023; Pmn et al. 2024)

Direct Dilution: For simple formulations, a specific amount of dapagliflozin is dissolved in an appropriate solvent, such as methanol, ethanol, or acetonitrile. This is used for straightforward quantification by UV-visible spectroscopy or HPLC.

Solvent Extraction: In more complex formulations, dapagliflozin is extracted using organic solvents like methanol or acetonitrile, which selectively dissolve the active pharmaceutical

ingredient (API), leaving behind excipients. This is especially useful for tablet formulations where multiple excipients are present.

Filtration and Sonication: After dissolution or extraction, the sample is filtered to remove particulate matter, ensuring a clear solution for HPLC or UV analysis. Sonication is often used to enhance the dissolution of dapagliflozin and improve extraction efficiency.

pH Adjustment: Buffer solutions may be employed to adjust the pH and improve the solubility of dapagliflozin in aqueous media, particularly for formulations that require specific solubility conditions to ensure accurate quantification.

2. Sample Preparation from Biological Fluids (Plasma, Serum, Urine)

The analysis of dapagliflozin in biological fluids is more challenging due to the presence of proteins, lipids, and other endogenous substances. The following strategies are typically used:

Protein Precipitation: Organic solvents such as acetonitrile or methanol are added to plasma or serum samples to precipitate proteins, which are then separated by centrifugation. The supernatant containing dapagliflozin is collected for further analysis.

- **Liquid-Liquid Extraction (LLE):** In this method, dapagliflozin is extracted from biological fluids using a suitable organic solvent (e.g., dichloromethane or ethyl acetate) that is immiscible with the aqueous phase. The organic phase, containing the drug, is separated, evaporated to dryness, and reconstituted in a solvent for analysis (Liu et al. 2023; Kuoni et al. 2023; Pmn et al. 2024).
- **Solid-Phase Extraction (SPE):** This method involves passing the biological sample through a cartridge containing a solid adsorbent. Dapagliflozin binds to the adsorbent, while impurities are washed away. The drug is then eluted using a suitable solvent, concentrating the analyte and improving the overall sensitivity and specificity of the analysis (Liu et al. 2023; Pmn et al. 2024).
- **Ultrafiltration:** Biological fluids are passed through a filter with a molecular weight cut-off to separate smaller molecules like dapagliflozin from larger proteins and macromolecules. This approach is commonly used in pharmacokinetic studies to ensure a clean sample for analysis (Liu et al. 2023; Kuoni et al. 2023).
- **Drying and Reconstitution:** After extraction, the organic solvent is often evaporated under a stream of nitrogen or in a vacuum evaporator. The residue is then reconstituted in a suitable mobile phase or solvent, making it ready for analysis by techniques such as HPLC or LC-MS (Liu et al. 2023; Kuoni et al. 2023).

- These sample preparation techniques are critical for isolating dapagliflozin from complex biological matrices and ensuring the precision and accuracy of the analysis in both clinical and research settings.

Estimation of Dapagliflozin by UV Spectrophotometry

UV spectrophotometry is a simple and cost-effective method for the estimation of dapagliflozin, both alone and in combination with other drugs. It provides rapid analysis with minimal sample preparation, making it suitable for routine quality control of single-drug formulations. However, in combination drug formulations, its limitations in selectivity and sensitivity may necessitate more advanced analytical techniques. Table 1 shows the UV-Spectrophotometry method for the estimation of Dapagliflozin alone and with another drug.

Table 1: UV-Spectrophotometry method for the estimation of Dapagliflozin alone and with another drug

Sr. No.	Method	Drugs Estimated	Method Details	Ref.
1	UV-Spectrophotometry	Dapagliflozin and Saxagliptin	Method (A) is based on the ratio difference method; Method (B) is ratio subtraction with constant multiplication; while Method (C) is a second derivative method and Method (D) is a partial least-squares method. **Results:** The calibration curves for dapagliflozin and saxagliptin were linear within the concentration range of 2.50-50.0 μg/mL and 5.0-60.0 μg/mL, respectively.	(Elhassan et al. 2023)
2	UV-Spectrophotometry	Dapagliflozin and Saxagliptin	Method A, first derivative method based on measurement of absorbance at two wavelengths 225 nm and 217 nm and methanol solvent were employed in this method.	(Sharma, Vashist, and

				Vashist 2015)
3	UV-Spectrophotometry	Dapagliflozin and Saxagliptin	The absorption spectra of DPF and SXG were highly overlapped which completely hindered their simultaneous estimation at their λmax 224 nm and 209 nm, respectively. Thus, in this work three smart and simple univariate spectrophotometric methods were originally established and validated. These methods are; factorized zero order method (FZM), factorized derivative method (FDM) and factorized ratio difference method (FRM).	(Lotfy, Mohamed, and Elshahed 2019)
4	UV-Spectrophotometry	Dapagliflozin and Metformin	The UV spectrophotometric estimation of Dapagliflozin and Metformin was determined using the Q absorption ratio method at 222 nm and 232 nm respectively using water as diluent.	(Bhavyasri 2020)
5	UV-Spectrophotometry	Dapagliflozin and Metformin Hydrochloride	This method involve solving of first derivative method based on measurement of absorbance at two wavelengths 235 nm and 272 nm using UV visible spectrophotometer with 1cm matched quartz cells and methanol solvent were employed in this method.	(Jani, Shah, and Kapupara 2015)
6	UV-Spectrophotometry	Dapagliflozin, Saxagliptin and Metformin	The 1st approach works on the notion of unravelling pre-existing equations (simultaneous) by measuring absorbance at 223, 212 and 232.6 nm for dapagliflozin, saxagliptin and metformin hydrochloride, sequentially. The second method namely ratio difference	(D. B. Sen et al. 2023)

			spectroscopy works by evaluating the variation in amplitude at two dissimilar wavelengths in the ratio spectra. Whereas the derivative ratio spectrum zero-crossing approach (third approach) relied on the utilization of the derivative ratio signals at zero-crossing locations. The fourth approach is the double divisor-ratio spectra derivative approach in which the first derivative of ratio spectrum was acquired and the concentrations of all 3 drugs in their combination were quantified.	
7	UV-Spectrophotometry	Dapagliflozin, Saxagliptin	This Method involves solving of simultaneous equations based on measurement of absorbance at two wavelengths 222 nm and 276 nm (λmax of SAXA and DAPA) in phosphate buffer pH 6.8	(Bhadauria and Agarwal 2019)
8	RP-HPLC method, and UV-Spectrophotometry		Method A: RP-HPLC method, Method B: UV spectroscopic method. In method A, the drug showed linearity in the range of 25-150µg/ml with a correlation coefficient (r2) of 0.999, where as in method B, the linearity range was found to be 1-5µg/ml with a correlation coefficient of (r2) 0.999.	(Sanagapati et al. 2014)
9	Innovative UV Spectroscopic Methodologies	Dapagliflozin And Vildagliptin	The proposed research suggests five spectrophotometric methodologies namely simultaneous equation, absorbance ratio, second derivative zero crossing, ratio difference, and first derivative of ratio spectra methods for	(A. K. Sen et al. 2016)

			the simultaneous assessment of the combined tablet that are straightforward, fast, easy, accurate, and reproducible	
10	Stability-Indicating Ultraviolet (UV) method	Dapagliflozin And Vildagliptin	A UV-visible spectrophotometric technique was done. Double-distilled water was used as the dapagliflozin's diluent. Vildagliptin's diluent was 0.1 N NaOH. The diluent used in the dosage form that contains both vildagliptin and dapagliflozin was 0.1 N NaOH	(K and M 2024)
11	Smart eco-friendly mathematically manipulated UV spectroscopic methods	Dapagliflozin, Sitagliptin and Vildagliptin	The ratio spectra of series of sitagliptin, vildagliptin, and dapagliflozin were generated using dapagliflozin 7.5 µg/mL, sitagliptin 10 µg/mL, and vildagliptin 10 µg/mL as divisor than the ratio difference and ratio first derivative techniques were established. Also, the parent spectra of analytes were extracted from the mixture spectrum by successive mathematical filtration for quantification of individual analytes from the binary mixture without prior separation	(Attimarad et al. 2023)
12	UV spectroscopic methods	Dapagliflozin And Saxagliptin	This Method involves solving simultaneous equations based on the measurement of absorbance at two wavelengths 222 nm and 276 nm (λmax of SAXA and DAPA) in phosphate buffer pH 6.8.	(Kumar, Lavakesh, and Pushpendra 2020)
13	Dissolution methodology by	Dapagliflozin	The dissolution methodology was developed with apparatus II (paddle) in 900 mL of medium (simulated gastric fluid, pH 1.2), temperature set at 37 ±	(De Meira et al. 2017)

	UV spectroscopic methods		0.5°C, and stirring speed of 50 rpm. For the quantification, a spectrophotometric (λ = 224 nm) method was developed and validated.	
14	Spectrophotometric Absorption Correction Methods	Dapagliflozin and Metformin Hydrochloride	By keeping Dapagliflozin and Metformin hydrochloride apart, a distinct spectrum was generated, displaying absorption maxima peaks (max) at 275nm (DAPA), and 245nm (MET). A method for solving equations is based on measuring the absorbance of two wavelengths, 275nm, and 245nm	(Dalal et al. 2024)
15	Simultaneous Spectrophotometric Estimation	Metformin (MET), Saxagliptin (SXG), and dapagliflozin (DGF)	Methanol: water (80:20 v/v) was used to make the standard and sample solutions. MET, SXG, and DGF had maximum values of 232.0, 212.0, and 272.0nm, respectively.	(Suman and Chaubey 2021)
16	Spectrophotometric Absorption Correction Methods	Saxagliptin Hydrochloride and Dapagliflozin Propendiol Monohydrate	The method was based on determination of saxagliptin hydrochloride at an absorbance difference between 214.40 nm - 220.0 nm and sapagliflozin propendiol monohydrate at an absorbance difference between 208.0 nm - 209.0 nm.	(Suthar et al. 2018)
17	Vierdot's Method	Sitagliptin and Dapagliflozin	As per the requirements of Vierdot's method, 224 nm and 267 nm was selected as analytical wavelength for quantification of Sitagliptin and	(Patel et al. 1800)

			Dapagliflozin which is their respective λmax.	

Estimation of Dapagliflozin by HPLC

High-Performance Liquid Chromatography (HPLC) is a highly sensitive and precise method for the estimation of dapagliflozin in both single-drug and combination formulations. It allows the separation of dapagliflozin from impurities and other drugs, making it ideal for stability studies, impurity profiling, and complex formulations. HPLC is widely used for regulatory compliance due to its accuracy and reproducibility. Table 2 shows HPLC and UPLC method for the estimation of Dapagliflozin alone and with another drug.

Table 2: HPLC and UPLC method for the estimation of Dapagliflozin alone and with another drug

Sr. No.	Method	Drugs Estimated	Method Details	Ref.
1	Stability-Indicating RP-HPLC Method	Dapagliflozin	The proposed method utilizes BDS column (at ambient temperature), gradient run (using mixture of acetonitrile and ortho phosphoric acid as mobile phase), effluent flow rate (1ml/min) and detection at 245nm using PDA detector.	(Sanagapati and Sreenivasa 2014)
2	Stability-indicating HPLC method	Metformin, Dapagliflozin, and Saxagliptin	The proposed method uses a Kromasil C18 column (150 × 4.6 mm, 5 μm) with column oven temperature of 30°C and mobile phase containing a mixture of 60% phosphate buffer (pH = 3) and 40% acetonitrile. The flow rate was set at 1.0 mL/min, and the injection volume was 10 μL. The detection was carried out at 230 nm using a photodiode array detector, and the total run time was 4 min.	(Vankalapati, Alegete, and Boodida 2022)

3	Stability Indicating HPLC method	Dapagliflozin	The adequate separation was carried using agilent C18 (4.6 ml*150,5 µm, mixture of acetonitrile: di-potassium hydrogen phosphate with pH-6.5 adjusted with OPA (40:60 %v/v) as a mobile phase with the flow rate of 1 ml/min and the effluent was monitored at 222 nm.	(Verma, Patel, and Patel 2017)
4	Stability-Indicating RP-HPLC Method	Dapagliflozin	Successful separation of drugs products is developed on a C_{18} column reversed-phase using mobile phase composition of Methanol: Water (75:25 v/v). The flow rate was adjusted to 1 mL/minute and the absorption maxima were observed at 230 nm	(Manoharan, Ismaiel, and Ahmed 2018)
5	Forced Degradation by RP-HPLC	Dapagliflozin	The stability-indicating HPLC method for assay included the use of Kromasil 100-5-C8 (100 mm × 4.6 mm) column, UV detector 224 nm, mobile phase composition involving a mixture of acetonitrile:water (52:48), and a flow rate of 1.0 mL/min.	(Chaudhari, Sahu, and Dande 2023)
6	Stability Indicating UHPLC Method	Vildagliptin and Dapagliflozin	A successful separation was achieved by using Agilent column C18 (4.6×100 mm) and mobile phase of Methanol: 0.1% Orthophosphoric acid (78:22) at a flow rate of 1.0 mL and detection wavelength of 234 nm.	(Galande et al. 2024)
7	AQbD based approach for UPLC procedure	Metformin, Vildagliptin, Dapagliflozin and Sitagliptin	The optimized procedure suggested by the desirability functions approach utilizing 49.3 volumes ethanol and 50.7 volumes pH 3.73, 0.1% Triethylamine buffer with 0.26 mL/min flow rate as mobile phase, Shield RP-18 (100 × 2.1 mm, 1.7 µm) column as a stationary phase with 4 min run time resulted in maximum desirability, 1.000. At 0.737 min, 1.425 min, 1.929 min and 2.645 min	(Narikimalli and Galla 2024)

			Metformin, Vildagliptin, Dapagliflozin and Sitagliptin retention times were observed respectively with acceptable resolution.	
8	Forced Degradation study by RP-HPLC	Dapagliflozin	Evaluation and validation carried out using the RP-HPLC ZORBAX (C18) column (250 x 4.6 mm, 5 µm particle size) with a mobile phase consisting of Phosphate Buffer: Acetonitrile: Methanol in a ratio of 55:40:05 (v/v/v) at a flow rate of 1 ml/min.	(Muruges an and Annapurn a 2022)
9	Kinetic Degradation Study with UHPLC	Dapagliflozin	Chromatographic separation done on a Symmetry® Acclaim™ RSLC 120 C18 column (100 mm, 2.1 mm, 2.2 µm), column temperature was maintained at 60 °C. Mobile phase was a mixture of potassium dihydrogen phosphate buffer, pH (3.5)—acetonitrile (50:50, v/v) at flow rate of 0.4 mL/min.	(Zaghary, Mowaka, and Hendy 2019)
10	Stability Indicating RP-Liquid Chromatogra phic Method	Dapagliflozin	A Phenomenex Gemini-NX C18 Column (250 mm, 4.6 mm, 5 µm) with a mobile phase containing of Methanol: Sodium 1-octanesulphonate in the proportion of 70:30 v/v was utilized. An injection volume of 20 µl with a flow rate of 1.0 ml/min	(Sreeniva sulu Sura, Rameswa ra Rao Modalava lasa, and Kothapall i 2018)
11	Quality by design (QbD) based bioanalytical RP-HPLC method	Dapagliflozin	The method was optimized using three levels and three-factor Box–Behnken statistical design (BBD). The mobile phase composition (acetonitrile % as *A*), flow rate (mL/min as *B*) and UV-wavelength (nm as *C*) selected as independent variable whereas area (AU as Y_1), retention time (min. as Y_2) and tailing factor (% as Y_3) selected as dependent variables.	(Ameedu zzafar et al. 2020)

12	HPLC method	Dapagliflozin and Metformin Hydrochloride	A Water-pak C18 column was used as the stationary phase with an isocratic mobile phase composed of 10 mM NaH2PO4 (pH 3.5 adjusted using ortho-phosphoric acid)—acetonitrile (65:35, v/v) containing 0.1% trimethylamine at a flow rate of 1.2 mL min−1 and a wavelength detector set at 225 nm.	(Nasser et al. 2018)
13	HPLC method	Metformin (MET), saxagliptin (SAX) and dapagliflozin (DAP)	Reversed-phase HPLC using Agilent C18 column (4.6 × 250 mm, 5 μm p.s.) with a mobile phase consisting of acetonitrile and acidic aqueous phase pH 3 with a photodiode array detection at 230 nm.	(El-Shoubashy et al. 2020)

Estimation of Dapagliflozin by HPTLC

High-Performance Thin-Layer Chromatography (HPTLC) is an efficient and flexible technique for the simultaneous estimation of dapagliflozin with other drugs in combination therapies. It offers high throughput, allowing the analysis of multiple samples at once, making it ideal for routine screening and quality control in multi-drug formulations. HPTLC is particularly useful for high-volume pharmaceutical labs. Table 3 shows HPTLC method for the estimation of Dapagliflozin alone and with another drug.

Table 3: HPTLC method for the estimation of Dapagliflozin alone and with another drug

Sr. No.	**Method**	**Drugs Estimated**	**Method Details**	**Ref.**
1	HPTLC Method	Dapagliflozin and vildagliptin	The methodology involved using aluminum plates layered with silica gel 60F254, and the solvent system comprised of acetonitrile, benzene, and glacial acetic acid (9:1:2 v/v/v). Densitograms were scanned at a wavelength of 210 nm.	(A. K. Sen et al. 2024)

2	HPTLC Method	Metformin Hydrochloride, Saxagliptin Hydrochloride, and Dapagliflozin	Separation was performed using aluminum HPTLC sheets coated with silica gel 60 F254 with a mobile phase consisting of a mixture of acetonitrile: 1% w/v ammonium acetate in methanol (9: 1, v/v). Scanning was performed at 210 nm.	(Abdelrahman, Maher, and Alzoman 2020)
3	HPTLC Method	Dapagliflozin	The present study describes the development and validation of a High-performance thin-layer chromatographic method for DAPA. The chromatographic separation was carried out on Merck precoated silica gel aluminum plate 60 F254.	(SUMA, R., and SHENOY 2019)
4	HPTLC Method	Dapagliflozin and Metformin Hydrochloride	Pre-coated silica gel 60 F254 aluminum plates using acetonitrile—ammonium acetate 10%—acetic acid (9:0.9:0.1, v/v) and a wavelength detector set at 225 nm.	(Nasser et al. 2018)
5	Forced degradation studies by HPTLC Method	Saxagliptin Hydrochloride, and Dapagliflozin	The proposed method was based on coupling high-performance thin-layer chromatography with dual wavelength detection at 225 and 210 nm for dapagliflozin and saxagliptin, respectively. Chromatographic separations were performed on silica gel 60-F254 aluminum plates with a mobile phase of hexane/methanol/ethyl acetate (4:2:4, v/v/v).	(Ahmed et al. 2020)
6	Stability-indicating HPTLC method	Metformin, Saxagliptin, and Dapagliflozin	The optimized chromatographic conditions used pre-coated silica gel 60 F254 HPTLC aluminum plates, mobile phase containing Methanol: 0.5 % aqueous ammonium sulphate (8:2, %v/v), pH 5.5, the saturation time of 20 min, and the solvent front of 95 mm. The	(Desai et al. 2022)

			detection was carried out at 222 nm using a UV detector.	
7	HPTLC method	Metformin (MET), saxagliptin (SAX) and dapagliflozin (DAP)	HPTLC in which drug solutions were applied to Merck HPTLC silica gel plates developed with a mixture of chloroform:methanol:water:acetic acid (7.4:2.6:0.5:0.01, *v/v*) and scanned at 224 nm.	(El-Shoubashy et al. 2020)

Conclusion

The estimation of dapagliflozin, both alone and in combination with other drugs, using UV spectrophotometry, HPLC, and HPTLC techniques provides reliable methods for ensuring the accurate quantification of this essential antidiabetic drug. Understanding the physicochemical properties, solubility, and effective sample preparation strategies for dapagliflozin is essential for its accurate estimation in both pharmaceutical and biological samples. UV spectrophotometry offers simplicity and rapid analysis, making it suitable for routine quality control in single-component formulations. However, its limitations in sensitivity and specificity in multi-component formulations necessitate the use of more advanced techniques like HPLC and HPTLC. HPLC remains the gold standard for its precision, accuracy, and ability to handle complex pharmaceutical matrices, particularly in stability testing and impurity profiling. HPTLC, with its high throughput capabilities, provides an efficient alternative for the simultaneous estimation of dapagliflozin with other drugs in combination therapies. Overall, each method has distinct advantages depending on the specific analytical requirements, such as sample complexity, sensitivity, and available resources. Future developments in analytical technologies will further enhance the sensitivity and reliability of these methods, ensuring the safe and effective use of dapagliflozin in clinical practice. These methods ensure the reliability of analytical techniques like HPLC, HPTLC and UV-visible spectroscopy, ultimately contributing to effective quality control, therapeutic monitoring, and pharmacokinetic studies.

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