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High-performance thin layer chromatography: A powerful analytical technique in pharmaceutical drug discovery

Abstract

Analysis of pharmaceutical and natural compounds and newer drugs is commonly used in all the stages of drug discovery and development process. High-performance thin layer chromatography is one of the sophisticated instrumental techniques based on the full capabilities of thin layer chromatography. The advantages of automation, scanning, full optimization, selective detection principle, minimum sample preparation, hyphenation, and so on enable it to be a powerful analytical tool for chromatographic information of complex mixtures of pharmaceuticals, natural products, clinical samples, food stuffs, and so on.

Key words: Drug discovery, HPTLC, natural products, planar chromatography.

Mahesh Attimarad, Mueen Ahmed K. K., Bandar E. Aldhubaib, Sree Harsha

Department of Pharmaceutical Sciences, College of Clinical Pharmacy, King Faisal University, Al-Ahsa, Saudi Arabia

Address for correspondence:
Dr. Mueen Ahmed, Department of Pharmaceutical Sciences, College of Clinical Pharmacy, King Faisal University, Al-Ahsa, Saudi Arabia.
E-mail: mueen.ahmed@gmail.com

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INTRODUCTION

Science and technology have never been so promising nor have delivered so many opportunities to improve health and extend lives, but continued investments are being invested in both the public and private sector, in spite of the current economic climate.[1-3] Increasing pharmaceutical industry success rates and delivering more medicines are very challenging, but very few predictive scientific and analytical tools are available.[4]

Research on drugs involves production control of bulk drug and final product, toxicological analysis of side effects of the drug or its possible impurities, and determination of the fate of a drug and its metabolites in an organism by the monitoring of body fluids.[5] Common criteria for drug evaluation include the quality and therapeutic value of the bulk drug and pharmaceutical product, identification studies, purity, content, uniformity, chemical and physical stability, and biological availability.[6,7]

PHARMACEUTICAL ANALYSIS AND HIGH-PERFORMANCE THIN LAYER CHROMATOGRAPHY—AN OVERVIEW

Analysis of pharmaceutical compounds and newer drugs is commonly used in all the stages of drug discovery and development process. These analytical techniques provide more accurate and precised data, not only supporting drug discovery and development but also postmarket surveillance.[8] Pharmaceutical analysts work regularly to improve the reliability of existing techniques to cope up the demands for better chemical measurements. Modern pharmaceutical analysis is mainly dominated by costlier instrumental analysis. Hence, many analysts' focus is on developing newer applications, discoveries, and new methods of analysis to increase the specificity and sensitivity of a method.[9,10]

Analytical methods used in drug analysis are diversified and are still being improved to find better solutions to satisfy manufacturers and institutions

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that test drug quality. Official documents dealing with the problem of QC of pharmaceutical products recommend diversified analytical techniques, with chromatographic methods playing a significant role in pharmaceutical analysis.[11]

Thin layer chromatography studies are among the key identity tests in most pharmacopoeial monographs. Pharmacopoeial standards are typically used by industry as a basis for meeting QC requirements and current good manufacturing practices (cGMPs). An extension of TLC is high-performance thin layer chromatography (HPTLC) is robust, simplest, rapid, and efficient tool in quantitative analysis of compounds. HPTLC is an analytical technique based on TLC, but with enhancements intended to increase the resolution of the compounds to be separated and to allow quantitative analysis of the compounds. Some of the enhancements such as the use of higher quality TLC plates with finer particle sizes in the stationary phase which allow better resolution.[12] The separation can be further improved by repeated development of the plate, using a multiple development device. As a consequence, HPTLC offers better resolution and lower Limit of Detection (LODs).

Visual detection is suitable for qualitative analysis, but a more specific detection method is needed for quantitative analysis and for obtaining structural information on separated compounds. UV, diode-array and fluorescence spectroscopy, mass spectrometry (MS), Fourier-transform infrared (FTIR), and Raman spectroscopy have all been applied for the *in situ* detection of analyte zones on a TLC plate. Van Berkel and coworkers have recently described couplings of TLC to atmospheric pressure chemical ionization[13] and electrospray ionization.[14-16] In both couplings, a special surface sampling probe is used for extracting the analyte on-line from the TLC plate to MS analysis.

The usage of HPTLC is well appreciated and accepted all over the world. Many methods are being established to standardize the assay methods. HPTLC remains one step ahead when compared with other tools of chromatography.[17]

One of the available chromatographic techniques is HPTLC, which is used for the identification of constituents, identification and determination of impurities, and quantitative determination of active substances. The use of modern apparatus such as video scanners, densitometers, and new chromatographic chambers, and more effective elution techniques, high-resolution sorbents with selected particle size or chemically modified surface, the possibility of combining with other instrumental methods, and development of computer programs for method optimization all make HPTLC an important alternative method to HPLC or gas chromatography. Specifically, HPTLC is one of the ideal TLC technique for the analytical purposes because of its increased accuracy, reproducibility, and ability to document the results, compared with standard TLC. Because of this, HPTLC technologies are also the most appropriate TLC technique for conformity with GMPs.[18] Today the comprehensive use of TLC in pharmaceutical analysis is demonstrated by the great number of artiicles published in this field.[19-30]

HPTLC remains one of the most flexible, reliable, and cost-efficient separation technique ideally suited for the analysis of botanicals and herbal drugs. Used with standardized procedures, it guarantees reproducible results, a vital element in the routine identification of complex fingerprints of plant extracts and pharmaceutical products.[19] It has established itself as the method of choice for handling complex analytical tasks involving herbal drugs and botanicals. The unique combination of state-of-art instrumentation, standardized procedures, and solid theoretical foundations enables it to deliver reliable, cGMP-compliant results time after time.

High-throughput analysis using HPLTC is being aimed at the rapid analysis of large numbers of compounds. This field has been expedited by the requirement to provide analytical support for multiple drug targets emerging from the field of molecular biology, human genetics, and functional genomics. Further, drivers for development have been in the support for the analysis of large compound libraries arising from parallel and combinatorial chemistry, and economic pressure to reduce time-to-market for new drug candidates.[20]

APPLICATIONS OF HPLTC

HPTLC is one of the most widely applied methods for the analysis in pharmaceutical industries, clinical chemistry, forensic chemistry, biochemistry, cosmetology, food and drug analysis, environmental analysis, and other areas. It is due to its numerous advantages, for example, it is the only chromatographic method offering the option of presenting the results as an image. Other advantages include simplicity, low costs, parallel analysis of samples, high sample capacity, rapidly obtained results, and possibility of

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multiple detection. Le Roux *et al*[31] evaluated a HPTLC technique for the determination of salbutamol serum levels in clinical trials and established as a suitable method for analyzing samples from the serum. Many lipids have also been analyzed and studied using HPTLC; 20 different lipid subclasses were separated using HPTLC with the reproducible and promising results. Many reports on studies related to clinical medicine have already been published in many journals. HPTLC is now strongly recommended in the analysis of drugs in serum and other tissues.[32]

HPTLC IN PHARMACEUTICAL PRODUCTS

HPTLC is also used in analyzing the purity and efficacy of many pharmaceutical preparations and dosage forms. Puranik *et al* developed and validated a simple, rapid, and accurate chromatographic methods (HPLC and HPTLC) for simultaneous determination of ofloxacin and ornidazole in solid dosage form. The amount of ofloxacin and ornidazole estimated as percentage of label claimed was found to be 100.23 and 99.61% with mean percent recoveries 100.47 and 99.32%, respectively. Both these methods were found to be simple, precise, accurate, selective, and rapid and could be successfully applied for the determination of pure laboratory prepared mixtures and tablets.[33]

A relatively fast, simple, and accurate method has been established for analysis of celecoxib, etoricoxib, and valdecoxib in pharmaceutical preparations. Małgorzata Starek *et al* reported that the procedure can be readily used for selective analysis of drugs, and repeatable results are obtained without interference from auxiliary substances.[34] Similarly, HPTLC method was successfully used to analyze fixed-dose tablets samples of lamivudine, stavudine, and nevirapine.[35] Two simple, accurate, and precise HPTLC methods have been established for the determination of mexiletine hydrochloride, an antiarrhythmic agent, in Mexicord capsules. The established methods are in accordance in terms of linearity, accuracy, precision, sensitivity, and specificity.[36]

Patel *et al* developed a simple and rapid HPTLC method and validated for quantitative determination of olanzapine on silica gel 60F254 layers using methanol-ethyl acetate (8.0 + 2.0, v/v) as the mobile phase. The developed method was found to be simplest among existing analytical methods.[37] A sensitive, simple, selective, precise, and accurate HPTLC method of analysis for paracetamol, diclofenac potassium, and famotidine both as a bulk drug and in tablet formulation was developed and validated.[38]

A novel HPTLC method has been developed and validated for quantitative determination of omeprazole in capsule dosage form. The method was validated according to the International Conference on Harmonization guidelines for accuracy, precision, linearity, specificity, and robustness. The method proposed can be used for QC and stability testing of different dosage forms such as tablets and capsules, as well as for bulk drug analysis of omeprazole.[39]

A new, simple HPTLC method for determination of etoricoxib and thiocolchicoside in combined tablet dosage form has been developed and validated. The pharmaceutical dosage form used in this study was Nucoxia-MR tablets. The method was validated with respect to linearity, accuracy, precision, and robustness in accordance with the International Conference on Harmonization guidelines. The method has been successfully applied to the analysis of drugs in the pharmaceutical formulation.[40]

HPTLC IN NATURAL PRODUCTS

The HPTLC technique is rapid, comparatively simple, robust, and extremely versatile. HPTLC not only confirm but also establish its identity. It is also an ideal screening tool for adulterations and is highly suitable for evaluation and monitoring of cultivation, harvesting, and extraction processes and testing of stability. A simple and reproducible method using HPTLC was successfully performed for the quantitative analysis of above diterpenoids in the root bark of *Photinia integrifolia*. In which Diterpenoids 1β,3α,8β-trihydroxy-pimara-15-ene (A), 6α,11,12,16-tetrahydroxy-7-oxo-abieta-8,11,13-triene (B) and 2α,19-dihydroxy-pimara-7,15-diene (C) were used as chemical markers for the standardization of *Photinia integrifolia* plant extracts.[41]

A simple HPTLC method has been developed for the simultaneous determination of isoorientin, isovitexin, orientin, and vitexin, both pure and in commercial samples of bamboo-leaf flavonoids. It was found that HPTLC is a simple, precise, specific, and accurate and can be used for manufacturing QC of bamboo-leaf flavonoids or for governmental regulatory purposes.[42]

Many such reports[43-49] present the evidence of utilization of HPLTC in fingerprinting analysis of drugs of natural origin, and hence, the increasing

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acceptance of natural products is well suited to provide the core scaffolds for future drugs; there will be further developments in the use of novel analytical techniques in natural products drug discovery campaigns.

HPTLC IN OTHER FIELDS

In recent years, HPTLC is a globally accepted practical solution to characterize small molecules in quality assessment throughout the developing world. HPTLC is used for purity control of chemicals, pesticides, steroids, and water analysis.[50] HPTLC is also widely used for analysis of vitamins, water-soluble food dyes, pesticides in fruits, vegetables, and other food stuffs.[51] Beate *et al*[52] reported the analysis of stem cell lipids by offline HPTLC-MALDI-TOF MS. HPTLC is useful in detecting chemicals of forensic concern,[53,54] including abuse drugs, poisons, adulterations, chemical weapons, and illicit drugs.

CONCLUSIONS

Applications of HPTLC for phytochemical analysis, biomedical analysis, herbal drug quantification, analytical analysis, finger print analysis, and HPTLC future to combinatorial approach, HPTLC-MS, HPTLC-FTIR and HPTLC-Scanning Diode Laser made HPTLC a power analytical tool in the field of analysis. It is noteworthy that utilization of instrumental HPTLC toward the analysis of drug formulations, Bulk drugs, natural products, clinical samples food stuffs, environmental, and other relevant samples will increase in the future.

REFERENCES

1. Zlatkis A, Kaiser RE. HPTLC, high performance thin-layer chromatography. Amsterdam: Elsevier Science and Technology; 1977.
2. Sethi PD. HPTLC: High Performance Thin Layer Chromatography: Quantitative Analysis of Pharmaceutical Formulations. CBS Publishers and Distributors ; 1996.
3. Arup U, Ekman S, Lindblom L, Mattsson JE. High performance thin layer chromatography (HPTLC), an improved technique for screening lichen substances. Lichenologist 1993;25:61-71.
4. Neumann C, Margot P. New perspectives in the use of ink evidence in forensic science: Part I. Development of a quality assurance process for forensic ink analysis by HPTLC. Forensic Sci Int 2009;185:29-37.
5. Sherma J. Review of HPTLC in Drug Analysis: 1996-2009. J AOAC Int 2010;93:754-64.
6. Butler MS. Natural products to drugs: Natural product-derived compounds in clinical trials. Nat Prod Rep 2008;25:475-516.
7. Gershell LJ, Atkins JH. A brief history of novel drug discovery technologies. Nat Rev Drug Discov 2003;2:321-7.
8. Sweedler JV. The continued evolution of hyphenated instruments. Anal Bioanal Chem 2002;373:321-2.
9. Albert K, Krucker M, Glaser T, Schefer A, Lienau A, Zeeb D. Hyphenated techniques. Anal Bioanal Chem 2002;372:25-6.
10. Wenlock MC, Austin RP, Barton P, Davis AM, Leeson PD. A comparison of physicochemical property profiles of development and marketed oral drugs. J Med Chem 2003;46:1250-6.
11. B Zycker, *et al*. ??? Plz provide rest of the authors name. The truth about drug innovation: Thirty-five summary case histories on private sector contributors to pharmaceutical science. Center for Medical progress at the 12 Manhattan University. Medical Progress Report No. 6, June 2008.
12. Reich E, Schibli A. Stationary Phases for Planar Separations - Plates for Modern TLC. LC GC . 2005;23:58-69.
13. Asano KG, Ford MJ, Tomkins BA, Van Berkel GJ. Self-aspirating atmospheric pressure chemical ionization source for direct sampling of analytes on surfaces and in liquid solutions. Rapid Commun Mass Spectrom 2005;19:2305-12.
14. Ford MJ, Van Berkel GJ. An improved thin-layer chromatography/mass spectrometry coupling using a surface sampling probe electrospray ion trap system. Rapid Commun Mass Spectrom 2004;18;1303-9.
15. Ford MJ, Deibel MA, Tomkins BA, Van Berkel GJ. Quantitative thin-layer chromatography/mass spectrometry analysis of caffeine using a surface sampling probe electrospray ionization tandem mass spectrometry system. Anal Chem 2005;77;4385-9.
16. Kertesz V, Ford MJ, Van Berkel GJ. Automation of a surface sampling probe/electrospray mass spectrometry system. Anal Chem 2005;77:7183-9.
17. ICH Harmonized Tripartite Guideline: Validation of Analytical Procedures: Text and Methodology Q2(R1). Geneva, Switzerland: International Conference on Harmonization; 2005.
18. Sudberg S, Sudberg EM, Terrazas J, Sudberg S, Patel K, Pineda J, *et al*. Fingerprint analysis and the application of HPTLC to the determination of identity and quality of botanicals, from an industry perspective. J AOAC Int 2010;93:1367-75.
19. Arup U, Ekman S, Lindblom L, Mattsson JE. High performance thin layer chromatography (HPTLC), an improved technique for screening lichen substances. Lichenologist 1993;25:61-71.
20. Morlock G, Schwack W. Determination of isopropylthioxanthone (ITX) in milk, yoghurt and fat by HPTLC-FLD, HPTLC-ESI/MS and HPTLC-DART/MS. Anal Bioanal Chem 2006;385:586-95.
21. Shah NJ, Suhagia BN, Shah RR, Patel NM. Development and validation of a simultaneous HPTLC method for the estimation of olmesartan medoxomil and hydrochlorothiazide in tablet dosage form. Indian J Pharm Sci 2010;69:834.
22. Shah NJ, Suhagia BN, Shah RR, Shah PB. Development and validation of a HPTLC method for the simultaneous estimation of telmisartan and hydrochlorothiazide in tablet dosage form. Indian J Pharm Sci 2010;69:202.
23. Shah NJ, Shah SK, Patel VF, Patel NM. Development and validation of a HPTLC method for the estimation of cefuroxime axetil. Indian J Pharm Sci 2010;69:140.
24. Eric-Jovanovic S, Agbaba D, Zivanov-Stakic D, Vladimirov S. HPTLC determination of ceftriaxone, cefixime and cefotaxime in dosage forms. J Pharm Biomed Anal 1998;18:893-8.
25. Morlock G, Schwack W. Determination of isopropylthioxanthone (ITX) in milk, yoghurt and fat by HPTLC-FLD, HPTLC-ESI/MS and HPTLC-DART/MS. Anal Bioanal Chem 2006;385:586-95.
26. Chaudhari BG, Patel NM, Shah PB, Modi KP. Development and validation of a HPTLC method for the simultaneous estimation of atorvastatin calcium and ezetimibe. Indian J Pharm Sci 2010;68:793.
27. Patel PM, Patel KN, Patel NM, Goyal RK. Development of HPTLC method for estimation of charantin in herbal formulations. Pharmacogn Mag 2010;2:224.
28. Fuchs B, Schiller J, Süss R, Nimptsch A, Schürenberg M, Suckau D. Capabilities and disadvantages of combined matrix-assisted laser-desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS) and high-performance thin-layer chromatography (HPTLC): Analysis of egg yolk lipids. JPC-J Planar Chromatogr-Modern TLC 2009;22:35-42.
29. Yan YZ, Xie PS, Lam WK, Chui E, Yu QX. Study on Triterpenoic Acids

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Distribution in Ganoderma Mushrooms by Automatic Multiple Development High Performance Thin Layer Chromatographic Fingerprint Analysis. J AOAC Int 2010;93:1384-9.
30. Müller A, Weiss SC, Schulz W, Seitz W, Albert R, Ruck WK, *et al*. Combination of different liquid chromatography/mass spectrometry technologies for the identification of transformation products of rhodamine B in groundwater. Rapid Commun Mass Spectrom 2010;24:659-66.
31. Le Roux AM, Wium CA, Joubert JR, Van Jaarsveld PP. Evaluation of a high-performance thin-layer chromatographic technique for the determination of salbutamol serum levels in clinical trials. J Chromatogr 1992;581:306-9.
32. Bernardi T, Tamburini E. An HPTLC-AMD method for understanding the metabolic behavior of microorganisms in the presence of mixed carbon sources. The case of Bifidobacterium adolescentis MB 239. JPC-J Planar Chromatogr-Modern TLC 2009;22:321-5.
33. Puranik M, Bhawsar DV, Rathi P, Yeole PG. Simultaneous Determination of Ofloxacin and Ornidazole in Solid Dosage Form by RP-HPLC and HPTLC Techniques. Indian J Pharm Sci 2010;72:513-7.
34. Chakraborthy GS. Determination Of Quercetin By HPTLC In Tagetes erectus Extract. J Glob Pharma Technol 2009;1:21.
35. Shewiyo DH, Kaale E, Ugullum C, Sigonda MN, Risha PG, Dejaegher B, *et al*. Development and validation of a normal-phase HPTLC method for the simultaneous analysis of lamivudine, stavudine and nevirapine in fixed-dose combination tablets. J Pharm Biomed Anal 2011;54:445-50.
36. Pietraś R, Skibiński R, Komsta Ł, Kowalczuk D, Panecka E. Validated HPTLC methods for quantification of mexiletine hydrochloride in a pharmaceutical formulation. J AOAC Int 2010;93:820-4.
37. Patel RB, Patel MR, Bhatt KK, Patel BG. Development and validation of an HPTLC method for determination of olanzapine in formulations. J AOAC Int 2010;93:811-9.
38. Khatal LD, Kamble AY, Mahadik MV, Dhaneshwar SR. Validated HPTLC method for simultaneous quantitation of paracetamol, diclofenac potassium, and famotidine in tablet formulation. J AOAC Int 2010;93:765-70.
39. Jha P, Parveen R, Khan SA, Alam O, Ahmad S. Stability-indicating high-performance thin-layer chromatographic method for quantitative determination of omeprazole in capsule dosage form. J AOAC Int 2010;93:787-91.
40. Rajmane VS, Gandhi SV, Patil UP, Sengar MR. High-performance thin-layer chromatographic determination of etoricoxib and thiocolchicoside in combined tablet dosage form. J AOAC Int 2010;93:783-6.
41. Yadav D, Tiwari N, Gupta MM. Simultaneous quantification of diterpenoids in Premna integrifolia using a validated HPTLC method. J Sep Sci 2011;34:286-91.
42. Wang J, Tang F, Yue Y, Guo X, Yao X. Development and validation of an HPTLC method for simultaneous quantitation of isoorientin, isovitexin, orientin, and vitexin in bamboo-leaf flavonoids. J AOAC Int 2010;93:1376-83.
43. Puranik M, Bhawsar DV, Rathi P, Yeole PG. Simultaneous determination of ofloxacin and ornidazole in solid dosage form by RP-HPLC and HPTLC techniques. Indian J Pharm Sci 2010;72:513.
44. Patel KG, Patel VG, Patel KV, Gandhi TR. Validated HPTLC Method for Quantitative Determination of Gallic Acid in Stem Bark of Myrica esculenta Buch.-Ham. Ex D. Don, Myricaceae. J AOAC Int 2010;93:1422-7.
45. Pagi KB, Lahiri SK, Yadav GK, Shah MB. Development and Validation of HPTLC Method for Determination of Betulinic Acid in Helicteres isora root Extract. Development 2010;2:851-5.
46. Chakraborthy GS. Quantitative estimation of ascorbic acid by HPTLC in different varieties of amla. J Young Pharm 2009;1:82.
47. Jadhav VM, Kedar US, Gholve SB, Kadam VJ. Development and Validation of HPTLC Method for Determination of Glycyrrhizin in Herbal Extract and in Herbal Gel. Development 2009;1:826-31.
48. Hong T, Jeong ML, Zahn M, Fay BA, Lee K, Hwangbo H, *et al*. Detection of the Potential Adulterant Teucrium chamaedrys in Scutellaria baicalensis Raw Material and Extract by High-Performance Thin-Layer Chromatography. J AOAC Int 2009;92:785-8.
49. Patel RK, Kanani RJ, Patel VR, Patel MG. Development and Validation of HPTLC Method for Simultaneous Quantification of Vasicine and Piperine in Vasavaleha. Int J 2010;2:14-7.
50. Weber W. Luminographic detection of toxicity with Vibrio fischeri (luminescent bacteria). CAMAG Bibiliography Service 2005;94.
51. Verbitski SM, Gourdin GT, Ikenouye LM, McChesney JD. Rapid Screening of Complex Mixtures by Thin-Layer Chromatography-Bioluminescence. Am Biotechnol Lab 2006;? :40-2.
52. Fuchs B, Schiller J, Süss R, Zscharnack M, Bader A, Müller P, *et al*. Analysis of stem cell lipids by offline HPTLC-MALDI-TOF MS, Anal Bioanal Chem 2008;392:849-60.
53. Dongre VG, Kamble VW. HPTLC detection and identification of heroin (diacetylmorphine) in forensic samples. Part III. J Planar Chromatogr-Mod TLC 2003;16:458-60.
54. Neumann C, Margot P. New perspectives in the use of ink evidence in forensic science: Part I. Development of a quality assurance process for forensic ink analysis by HPTLC. Forensic Sci Int 2009;185:29-37.

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