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NIR Spectroscopy: An Advancing Versatile Tool for Process Analytical Technologies in Pharmaceuticals

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ABSTRACT

Near-Infrared (NIR) Spectroscopy and imaging are fast and nondestructive analytical techniques that provide chemical and physical information of virtually any matrix. The Process Analytical Technology (PAT) promoted by the Food and Drug Administration (FDA) has motivated the Pharmaceutical Industry to increase utilization of newer analytical technologies to perform fast measurements of the critical quality attributes of Pharmaceutical materials, starting from raw materials and intermediates to finished products. PAT concept aims ensuring a predefined final product quality. Near IR spectroscopy is a tremendous and prevailing tool for Process Analytical Tool in Pharmaceutical Processes with applicability in multi-functional faces. NIR spectroscopy has been proved to be the most compatible technology with PAT. The present review is aimed to reconnoiter various applications of NIR spectroscopy with special emphasis on Pharmaceutical Processes involved in manufacturing of various dosage forms. The review will also discuss some points to be considered in implementing NIR as a process analytical tool.

Keywords: Near-infrared spectroscopy; Process analytical technologies; Pharmaceutical manufacturing; Quality assurance

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INTRODUCTION

Importance of Analytical Techniques for Pharmaceuticals

It is very important to check the purity of the pharmaceutical products to avoid detrimental effects in the humans. Hence, to remove it, there exist diverse analytical techniques in pharmaceuticals. Various techniques are essential like spectrophotometric and chromatographic. Quality of drugs can be improved by implementing various analytical techniques for better results. Analytical methods shall be non-toxic and free from harmful pollutants with

environmental aspects. Hyphenated techniques such as GC-MS, LC-MS have been used widely for Pharmaceutical product. Some analytical techniques like UV-Vis, flour metric and vibrational spectroscopes is also important for exploitation in pharmaceuticals to develop fastest method and reduction of solvents also Analytical methods play extreme role in pharmaceuticals from impurities detection to conclusion of structure identification and for safety and efficacy in patients. Some narrative analytical methods are also employed for the detection of pharmaceuticals like automatic sampling analysis, miniaturization and pattern recognition. Thus, it is suggested to use analytical methods in pharmaceuticals with exploitation of low cost diminution and easy, optimized and eco-friendly [1,2].

Importance of Vibrational Spectroscopy in Pharmaceutical Analysis

Importance of vibrational spectroscopies includes NIR, Raman and mid-IR techniques in analysis in development of method with a lesser amount of sample preparation without causing damage. They are also valuable in elucidation of structure to find molecules of structures and their metabolites. Qualitative and quantitative evaluation of drugs and have been fastest technologies with theoretically and practically relevant methods. NIR spectroscopy is very vital in vibrational because of identification of various polymers, bulk materials, assessment of quality and versatile techniques. Involvement of green chemistry for diminution of toxic-reagent harmful to people. It includes finding of volumetric analysis and turbidity in samples and analysis of plant tissues, organs and cells. The depiction of solids and crystals with chemo metrics and techniques such as PLS, TRS and LFR are efficient in this technique [3]. They are pertinent to identify API, counterfeit of drugs and evaluation of tablets. It is moreover the main utensils in the biological to study drug interaction and various techniques such as high-throughput screening, disease diagnosis and spectral pathology. Thus, vibrational spectroscopy is useful in pharmaceutical analysis to scrutinize drugs and determine the quantity of materials and substances with various techniques such as NIR-CI, FTIR, MIR and PLS.

NIR TECHNIQUE

Principle

NIR principle is based on the technique that a material would be immersed by NIR energy and then transmits or reflect into distinctive model as per physical and chemical characterization. Hence NIR technique can be competent for qualitative and quantitative analysis. The wavelength range among 780 and 2565 nm and wave number range among 12820-3959 cm^{-1} is the range where NIR is positioned. In this system light source sample was irradiated and then fascinated by the molecules only when the dipole moment is changed due to molecular ambiance. O-H, N-H, S-H and R-H groups are having higher dipole moment. Hence they are showing strong absorbance in NIR. Overtones and combination of bands in various elementary vibrations occurs in NIR due to -CH, -NH, -OH groups are having assessable bands of absorption which is due to multi-level energy transitions. Combination bands also seen in polyatomic molecules with the result of equivalent energy produce in altering of vibrational modes. The combination bands occur between 1900-2500 nm due to interactions takes place in vibrations. Stretching and bending absorption takes place in NIR technique (Figure 1). Stretching can be defined as a change occurs in bond-axis and no changes occur in bond-angle whereas bending is defined as changes occur in bond-angle and no changes occur in bond-axis [4-6].

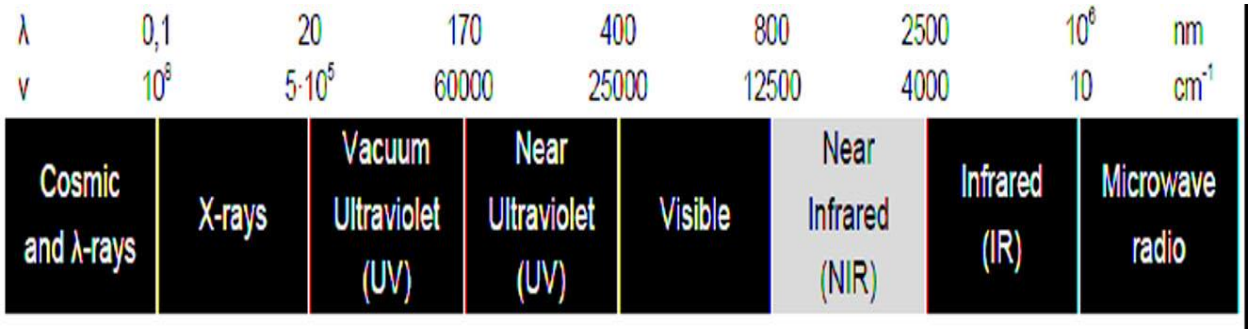

Figure 1. Electromagnetic spectrum

Instrumentation

Instrumentation of NIR is suitable having fastest and console analysis of various samples. The light source, wavelength selection system, sample holder, sample presentation interface and a detector are present. In light source the beam is generated and irradiation takes places and the sample examination takes place. Light source which is valuable is halogen light having tungsten filament and quartz window used to emanate incessant spectrum in the ranges of 320 nm to 2500 nm. Whereas LEDs (Light Emitting Diodes) are capable to secrete up to 1600 nm. The halogen lamps have necessity of wavelength selection system, while LEDs do not necessitate this. Samples presented are available in transmittance, trans reflectance and reflectance in the instrumentation of NIR (Figure 2). NIR technique is alienated into two types based on the selection of wavelength namely dispersive and non-dispersive instruments. Mono-chromators are mainly used in dispersive techniques. Conventional filters, Fourier transform (FT)-NIR type and AOTFS (Acusto-Optic Tunable Filters) are useful for non-dispersive techniques. Detectors used in instrumentation is single-channeled detectors like PbS and InGaAs and multi-channeled detectors like CCD's and Array detectors to detect the sample and obtain the spectra (Figure 3).

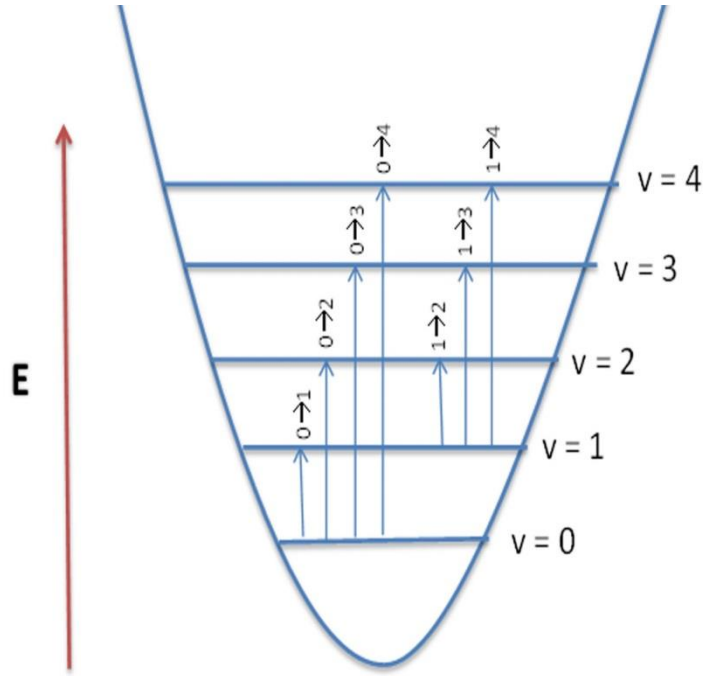

Figure 2. Anharmonic model

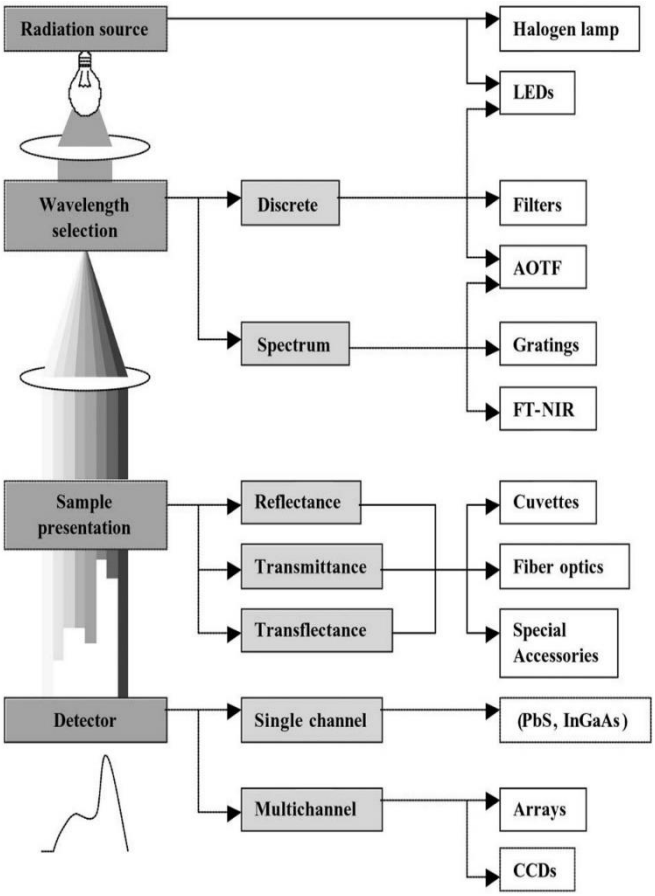

Figure 3. Principle features of NIR equipments

Advantages

- Fast and ability to detect sample splendidly
- Sample training is not mandatory and on-line monitoring is feasible
- Reduction in costs and reagents and parameters such as viscosity, density and particle size are evaluated
- NIR technique is comfortable and easy to use techniques and it's radiation have enhanced dissemination power
- Non-destructive, non-contact and effortless skill of analysis
- NIR method is precise, habitual and simple for installation and maintenance
- It is also connected to tablet monitoring and manufacturing process.

Recent Applications of Near IR Spectroscopy

Recent applications of Near Infrared spectroscopy described in Table 1.

Process Analytical Technology

Process Analytical Technology (PAT) may be defined as "a system for designing and controlling manufacturing through timely measurements (i.e. during processing) of critical quality and performance attributes for raw and in-process materials and also processes with the goal of ensuring final product quality into the product and

manufacturing processes and their continuous process improvement". The strategy of PAT includes identification and perceptive of critical parameters, Control of significant parameters and ascertain safety and quality.

Table 1. Recent advancements of Near IR spectroscopy other than process analytical technique

Sr.no	Advancements	Uses
1	Mineral identification	Distinguish minerals by NIR method through remote sensing
2	Technique for solid-state characterization	To identify and scrutinize solid compounds, drugs and excipients
3	Food safety	Enlightening of food sources by obtaining spectrum
4	Soil determination	Exemplify content of copper in soils using PLS method
5	Neuroscience	The technique is employed with light emitting diode technique in neurological for recognition of neuronal disorders
6	Plant-tissue analysis	NIR is involved to determine spectral information.
7	Fiber-optics biosensors	Performance are equipped with fiber optics biosensing for determination of various bacteria and species
8	Blood-glucose monitoring	Investigate of glucose levels with help of spectra
9	Determination of beef-quality	NIR probes are used to establish quality of beef with visible region
10	Aqua-photomics technique	The system is engaged with NIR to perceive pollutants in water and agriculture mainly cadmium compound.
11	LED based NIR sensors for human kidney lump diagnostics	Used for exposure of cancerous cells in kidney

Implementation of Process Analytical Technology

Identification: To identify the vital parameters and uniqueness of quality in the process.

Monitoring: After identifying the parameter monitoring takes place. Monitoring process takes place by automatic or on-line analysis to determine quality characteristics with various analytical techniques.

Analysis: After monitor and identification of critical parameters analysis is done to assess significant parameters including the methods to be validated and verified.

Controlling: After doing analysis it is necessary to control the process and result should be within limits.

Reporting: Report is obligatory document to implement the process.

APPLICATIONS

Applications of Process Analytical Technology

- Radiochemistry
- Bio-PAT
- Chemo-metrics
- Crystallization
- Bio-pharmaceuticals
- Reaction monitoring
- Raw-material identification

Application of NIR in PAT

Summary of applications of Near Infrared spectroscopy in manufacturing process is provided in Table 2.

Table 2. Summary of application of NIR as a PAT tool

Sr. No	Process	Parameters	Content measured	References
1	Tablet manufacturing	Process of blending	Pharmaceutical powders	[7]
		Powder	Powder flow	[8]
		Comparison of NIR and Raman for tablet	Amlodipine and Valsartan	[9]
		Drugs and excipients	Solid-dosage forms	[10,11]
		Roller compactor ribbon density	Microcrystalline cellulose, lactose and magnesium stearate	[12]
		Powder blend Dissolution	Beta-carotene, riboflavin, ferrous fumarate, ginseng and ascorbic acid	[13,14]
		Active content of uncoated tablet	Allopurinol immediate release tablets	[15]
		Content and hardness of tablet	API content and validation	[16]
		Raw-material identification	Mirtazapine	[17]
		API in tablet	Gingko biloba	[18]
		Drying process		
		Hot-melt extrusion	Caffeine	[19]
		Production of tablet	Frozen vials	[20]
			Indomethacin	
			Zidovudine and Lamivudine	[21]
2	Biological	Cell-culture	Animal	[22]
		Composition of bio-degradable material	Polysaccharides and proteins	[23]
		Monoclonal-antibodies	Chinese hamster ovary cell	[24]
3	Extraction process	Liquid-liquid extraction	Gardeniae fructus	[25]
4	Distillation process	Blended with ethanol	Gasoline	[26]
5	Glucose concentration of Chinese hamster ovary cell development	On-line prediction	Glucose	[27]
6	Traditional Chinese medicines	Physical and chemical characterization	Shenzhiling oral liquid	[28]
7	Amylose content in rice	On-line monitoring	Varieties of rice	[29]
8	Liposomes	In-line monitoring	Freeze-dried Prednisolone sodium phosphate loaded long-circulating liposomes	[30]

CONCLUSION

NIR is an admirable for qualitative and quantitative analysis in Pharmaceuticals as well in other industries. PAT collaboration with NIR is emerging concept to diminish errors and some applications of NIR united with process analytical tool is also a major impact in industry to determine the quality of product and its specifications.

REFERENCES

1. KK Mulpuri; B Das; M Haseeb, U Rahman. *Int J Res Pharm Nano Sci*. **2015**, 4: 19-27.
2. A Nikolaou. *Glob Nest J*. **2013**, 15: 1-12.
3. HRN Bonfilio; R De Araujo; MB Salgado. *WSEAS Trans Biol Biomed*. **2010**, 7: 316-338.
4. F Ahmed; R Dewani; MK Pervez; SJ Mahboob; SA Soomro. *Bulg Chem Commun*. **2016**, 48: 71-77.
5. P Prajapati; R Solanki; V Modi; T Basuri. *Int J Pharm chem anal*. **2016**, 3: 117-123.
6. C Chandarana; V Modi; T Basuri; P Prajapati. *Int J Innov Pharm Sci Res*. **2016**, 4: 269-286.
7. R Tanaka; N Takahashi; Y Nakamura; Y Hattori; K Ashizawa; M Otsuka. *Anal Sci*. **2017**, 33: 41-46.
8. MA Alam; Z Shi; JK Drennen; CA Anderson. *Int J Pharm*. **2017**, 526: 199-208.
9. T Casian; A Reznek; AL Vonica-Gligor; J Van Renterghem; T De Beer; I Tomuță. *Talanta*. **2017**, 167: 333-343.
10. ME Crowley; A Hegarty; MAP McAuliffe; GE O'Mahony; L Kiernan; K Hayes; AM Crean. *Eur J Pharm Sci*. **2017**, 102: 103-114.
11. P Durão; C Fauteux-Lefebvre; JM Guay; N Abatzoglou; R Gosselin. *Talanta*. **2017**, 164: 7-15.
12. J Smetiško; S Miljanić. *J Pharm Biomed Anal*. **2017**, 145: 322-330.
13. PF Chavez; PY Sacré; C De Bleye; L Netchacovitch; J Mantanus; H Motte; M Schubert; P Hubert; E Ziemons. *Talanta*. **2015**, 144: 1352-1359.
14. M Blanco; M Alcalá. *Anal Chim Acta.* **2006**, 557: 353-359.
15. SS Rosa; PA Barata; JM Martins; JC Menezes. *J Pharm Biomed Anal*. **2008**, 47: 320-327.
16. PR Wahl; I Pucher; O Scheibelhofer; M Kerschhaggl; S Sacher; JG Khinast. *Int J Pharm*. **2017**, 518: 130-137.
17. PJ Van Bockstal; L De Meyer; J Corver; C Vervaet; T De Beer. *J Pharm Sci.* **2017**, 106: 71-82.
18. MT Islam; N Scoutaris; M Maniruzzaman; HG Moradiya; SA Halsey; MSA Bradley; BZ Chowdhry; MJ Snowden, D. Douroumis. *Eur J Pharm Biopharm*. **2015**, 96: 106-116.
19. S Grangeiro Junior; L de Moura França; MF Pimentel; MM Albuquerque; DP de Santana; AKM Santana; JAL Souza; SS Simões. *Microchem J*. **2015**, 118: 252-258.
20. M Rüdt; T Briskot; J Hubbuch. *J Chromatogr A.* **2017**, 1490: 2-9.
21. M Li; B Ebel; F Courtès; E Guedon; A Marc. *Austin J Anal Pharm Chem*. **2016**, 3: 1-5.
22. DF Barbin; NA Valous; AP Dias; J Camisa; EY Hirooka; F Yamashita. *Mater Sci Eng C*. **2015**, 56: 274-279.
23. A Hakemeyer; U Strauss; S Werz; GE Jose; F Folque; JC Menezes. *Talanta*. **2012**, 90: 12-21.
24. L Tao; Z Lin; J Chen; Y Wu; X Liu. *J Pharm Biomed Anal*. **2017**, 145: 1-9.
25. Y Wu; Y Jin; Y Li; D Sun; X Liu; Y Chen. *Vib Spectrosc*. **2012**, 58: 109-118.
26. RR de Oliveira; RHP Pedroza; AO Sousa; KMG Lima; A de Juan. *Anal Chim Acta*. **2017**: 985: 41-53.

27. A Kozma; E Hirsch; S Gergely; L Párta; H Pataki; A Salgó. *J Pharm Biomed Anal*. **2017**, 145: 346-355.
28. R Liu; Q Sun; T Hu; L Li; L Nie; J Wang; W Zhou; H Zang. *Mol Biomol Spectrosc*. **2018**, 192: 75-81.
29. PS Sampaio; A Soares; A Castanho; AS Almeida; J Oliveira; C Brites. Food Chem. **2018**, 242: 196-204.
30. B Sylvester; A Porfire; PJ Van Bockstal; S Porav; M Achim; T De Beer; I Tomuţă. *J Pharm Sci.* **2018**, 107: 139-148.