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RESEARCH ARTICLE

Pharmaceutical Application of Fast Raman Hyperspectral Imaging with Compressive Detection Strategy

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Abstract This article reports a new Raman imaging instrument based on liquid crystal spatial light modulator compressive detection (LC-SLM-CD) strategy that could provide a fast way of testing the composition of solid formulations. In this study, the LC-SLM-CD strategy is employed to investigate the qualitative and relative quantitative distribution of two commonly used ingredients, acetaminophen and lactose in a pharmaceutical tablet. The spatial distribution of each component is formed based on the responses of the samples to the partial least squares filters built into the instrument. This technique has proven to be a fast and feasible technique for noninvasive determination of blend quality and for determination of relative abundances of each component in a tablet.

Keywords Raman spectroscopy · Hyperspectral imaging · Compressive detection · PLS

Introduction

Throughout the formulation development of solid dosage forms such as tablets, the goal is that every unit of final drug product will have the desired performance with identical therapeutic effects. The drug's physical properties, and ultimately its performance, highly depend on the quantities of the components and how well the final product is blended. A relatively small degree of deviation from the optimum specifications may yield a widely varying therapeutic performance. Thus, determining the blend quality and generating statistical blending data quickly is imperative for production and is critical for process analytical technology (PAT) to reduce the cost and delay time in a production cycle.

High-performance liquid chromatography, UV/visible spectroscopy, or mass spectrometry are widely used tools to determine the gross composition of formulations, but none of them provides any insight into the distribution of the components within the analyzed sample. Dissolution testing, on the other hand, is employed to obtain drug release profiles, indicating the duration of component release. However, these currently used methods provide no information regarding the root cause or structural basis for changes in the dissolution profile. Thus, it is impractical and inefficient to quickly trace the failure and correct it with these traditional tools. In addition, these standard quality control techniques are destructive, laborious, and time consuming, which stalls the production awaiting test results from the quality control laboratory following the tablet compaction process. In fact, the analysis to validate the quality of blending takes more time than actual blending process.

Spectroscopic techniques, such as Raman and near infrared (NIR), can provide a rapid, nondestructive, means of monitoring a manufacturing process. Both techniques measure similar molecular vibrations. In imaging mode, they can provide an assessment of the content uniformity of a sample in terms of the spatial distribution of the ingredients. While Raman spectra is characterized by narrower peaks, giving better information on molecular level, wide, overlapping NIR bands are difficult to assign. However, NIR interrogates larger areas than Raman in shorter times. A study by Jerez-Rozo et al. evaluated the use of NIR and Raman mapping to investigate the spatial distribution of the components of polymeric films [1].

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