Real-time monitoring of 3D-printed personalised tablets using HME and FDM technologies

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Abstract

The rising prevalence of diabetes and its associated co-morbidities, such as hypertension, presents significant challenges to healthcare systems. Hydrochlorothiazide (HCTZ), commonly prescribed for managing both hypertension and fluid retention in diabetic patients, suffers from poor solubility and permeability, which can hinder its therapeutic effectiveness. Research suggests that 3D-printed tablets can overcome these issues and enhance the bioavailability of HCTZ and other poorly soluble drugs by enhancing the solubility and permeability of the Active Pharmaceutical Ingredient (API) in the drug product.

This study aims to assess the potential of hot melt extrusion (HME) and fused deposition modelling (FDM) 3D printing techniques to manufacture high-quality tablets with enhanced therapeutic outcomes, using drug-loaded filaments. However, ensuring the homogeneity of the drug within the filaments is challenging and requires real-time and continuous monitoring of the extrusion process, to reduce inconsistencies that can lead to variability in dosage and therapeutic effectiveness.

Raman spectroscopy as a process analytical technology (PAT) tool is used for inline process monitoring and optimisation to extrude homogeneous filament with the required dose. In addition, extensive offline physicochemical characterisations including Raman imaging, UV-Visible spectroscopy, Scanning Electron Microscopy (SEM), Differential Scanning Calorimetry (DSC) and X-Ray Diffraction (XRD) were performed to better understand the effect of extrusion on HCTZ properties and its distribution homogeneity within the extruded filaments.

Obtained results revealed that HCTZ underwent a transformation from its crystalline to amorphous form during extrusion which significantly enhanced its solubility. The study also confirmed that the extrusion process resulted in uniform drug distribution. These findings suggest that HME-FDM approach combined with Raman PAT for real-time process monitoring can be used to manufacture high-quality products, enhance the bioavailability of HCTZ and potentially improve treatment outcomes for diabetic patients with hypertension and other co-morbidities. This study opens new possibilities for improving the bioavailability of poorly soluble drugs and enabling more personalised treatment options.

Keywords: 3D printing, PAT, HME, FDM, Personalised medicine