Analysis and detection of counterfeit drugs with hyperspectral cameras

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I. INTRODUCTION

Development, production and marketing of drugs involves a significant amount of investment, and is therefore prone to the production of illegal or counterfeit products. In addition to being illegal, counterfeit drugs may cause high health risks. Currently, many countries invest money in governmental agencies to track these illegal and counterfeit drugs. In parallel, new technologies and methods have been developed for this purpose, including hyperspectral imaging. The aim of this study is to assess the relevance of such systems to support the detection of these counterfeit and illegal products.

II. EXPERIMENTAL TECHNIQUES

Genuine and counterfeit tablets containing sildenafil (i.e. Viagra®) were investigated in the spectral range of 400-2500 nm. The tablets were scanned with SPECIM VNIR (400-1000 nm) and SWIR (1000-2500 nm) hyperspectral imaging systems in order to measure their spectral reflectance. The imagers were mounted on a motorised linear stage and attached to an optial rail structure. Illumination of the object (tablet) was obtained via 3 Halogen bulbs located at 45 degrees to one side of the tablet. For each image, the measured raw data (A/D sensor counts) was converted into units of reflecatance. The hypercube data containing the refletance spectra was calibrated and normalised. All data acquisition, pre-processing and multivariate analysis was performed using ENVI software and Matlab.

Prior to data acquisition, the system was calibrated following a standard procedure of setting exposure and focus. The aspect ratio of the hyperspectral images was adjusted by tuning the speed of the motorised linear stage.

For each scan, two calibration images were captured; 1) a dark reference (no light entering the imager), used to remove the contribution of the sensor dark current, 2) a white reference, used to measure the applied illumination level. Both calibration images were used to convert the imager raw data into normalised data. The non-uniformity of the illumination was also addressed and corrected by the normalisation processing step. Furthermore, Principal Component Analysis (PCA) algorithms were employed to visualise the applied hyperspectral imaging method.

III. RESULTS AND ANALYSIS

According to the results, both the VNIR and SWIR systems were (are) suitable to separate counterfeit tablets of Viagra® from genuine ones. Although the PCA highlighted that the tablets were most likely made of the same active principal ingredient (API), there were distinct spectral differences in the regions of 850-1000 nm, 1550 and 2250 nm. The difference in spectral properties are due to variation in the chemical composition of genuine and counterfeit drugs (active pharmaceutical ingredient and excipients) and/or another internal structure resulting from a different production technology. Furthermore, the SWIR spectral camera highlighted that the counterfeit tablets were not as homogeneous as the genuine ones.

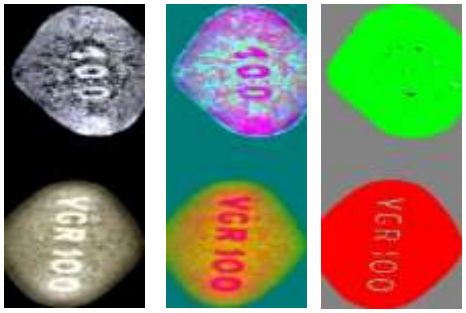

Figure 1: Images of the counterfeit (top) and genuine (bottom) Viagra® pills a) false RGB b) PCA c) classes

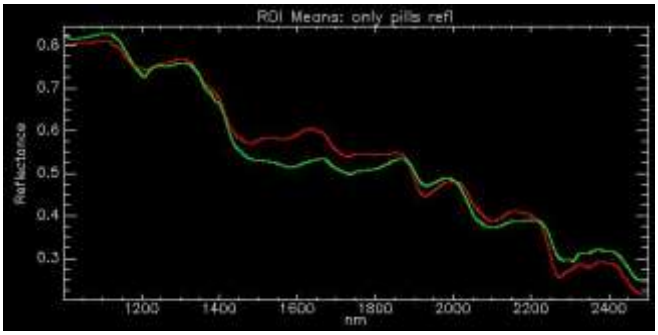

Figure 2: Spectral reflectance data for each class; green (counterfeit) and red (genuine)

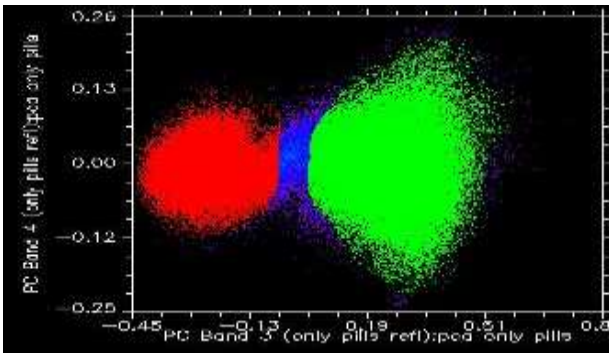

Figure 3: 2D scatter plot of PC4 vs PC3

The images in Figure 1 were taken with the SWIR camera and a microscopic (close-up) lens (24 µm spatial resolution at sample). The PCA image includes background removal (Red-PC1; Green-PC2; Blue-PC3) and the classes image was obtained by displaying a 2D scatter plot (PC4 vs PC3) and selecting clusters.

Figure 2 shows the spectral reflectance of the genuine (red) and counterfeit (green) tablets. This data was taken using the SPECIM SWIR (1000-2500 nm) hyperspectral imaging system. The use of imaging in the SWIR spectral range provides the reflectivity vector over a wide wavelength range independent of illumination in the visible part of the spectrum, and eliminates the effect of non-uniform scattering of light on the object (tablet) surface. Furthermore, radiation of a longer wavelength, in accordance with the Lambert-Beer law, penetrates deeper into the analysed materials and therefore is not as sensitive to reflection from the surface (and consequently the method of sample illumination).

Furthermore, the use of radiation in the SWIR spectral range means that not only the tablet surface is imaged but also the properties underneath the surface (from a few to a few hundred microns depending on the material structure and properties) [1].

IV. CONCLUSION

Hyperspectral imaging, supported by mathematical, image analysis and image processing methods, enables one to distinguish between genuine and counterfeit drugs with near 100% confidence (probability). Crucially, hyperspectral imaging is a non-destructive technique, which allows for a screening test to be performed – enabling numerous samples to be examined simulateneously. This reliable and temporally efficient method could allow for quick withdrawal of counterfeit drugs from the market.

The use of PCA allows for effective visualisation of ingredient distribution for both the genuine and counterfeit tablets.

The use of hyperspectral imaging in the range of 1000-2500 nm has a definite advantage over imaging in the range of 400-1000 nm becuase it enables one to analyse not only the outer coating of the tablet, but up to a few hundred microns in depth. In addition, longer wavelength radiation is less sensitive to non-uniform illumination and radiation scattering at the edges of the tables and any embossment, which is especially important for rounded objects (such as tablets) as well as non-laboratory analysis.

Based on the above, we can conclude that VNIR and SWIR hyperspectral imaging can be successfully applied for distinguishing genuine from counterfeit drugs.

[1] F.C. Clarke, S.V. Hammond, R.D. Jee, A.C. Moffat, “Determination of the information depth and sample size for the analysis of pharmaceutical materials using reflectance near-infrared microscopy”, *Appl. Spectrosc.* 56 (2002) 1475-1483