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The pivotal role of modern pharmacognosy in the quality control of herbal medicines

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To ensure the safety and efficacy of herbal products, researchers are constantly exploring alternative/improved methods to develop robust technical standards for quality. While several analytical approaches are currently in use for routine quality control in the food, agriculture and pharmaceutical industries, many conventional techniques may fall short on speed of analysis, holistic approach and cost-effectiveness due to the complex nature of herbal products. In the continued quest to develop protocols that are fast, non-destructive, easy to use and offer a comprehensive analysis of the whole plant metabolome, the potential of some novel analytical techniques such as vibrational spectroscopy, including mid- (MIR) and near-infrared (NIR), nuclear magnetic resonance (NMR), hyperspectral imaging (HSI) and atmospheric solids analysis probe (ASAP) has been investigated. The aforementioned spectroscopy techniques offer the advantage of non-destructive analysis of both raw materials and products without use of solvents. Additionally, acquired spectra contain chemical information on almost the complete metabolome including chemical and physical properties (HSI). As a fast and simple method, ASAP also allows for low cost and direct analysis of samples. Our research has focussed on quality concerns surrounding herbal products where issues of raw material substitution and spiking/contamination of natural products with synthetic or natural compounds have taken centre stage. A few examples are presented to demonstrate the feasibility of using vibrational spectroscopy and hyperspectral imaging for the routine quality monitoring of herbal raw materials through;

- 1) successful differentiation of two commercially significant *Harpagophytum* species
- 2) distinction of toxic *Aristolochia fangchi* from the non-toxic and commercially favoured *Stephania tetrandra*
- 3) differentiation of ginseng species that are used interchangeably despite significant chemical differences as demonstrated by HSI and MIR spectral correlation measurements
- 4) fast and simple quantitative prediction of marker molecules such as uzarin in Uzara (*Xysochloa undulatum*)
- 5) the novel application of ASAP technology to detect contamination of commercial Henna samples with the synthetic compound *p*-phenylenediamine (PPD).

The proposed alternative quality control methods can accurately authenticate species, detect adulteration and quantify biomarkers and thus be implemented in the herbal industry based on application.