Turmeric fraud: rapid authenticity screening using benchtop analytical instruments

Nathan O'Neill,[1] María J. Marín,[1] Lionel Hill,[2] Simon Kelly[3], E. Kate Kemsley[1,4]

[1]*School of Chemistry, Pharmacy and Pharmacology, University of East Anglia, Norwich Research Park, Norwich, NR4 7TJ, United Kingdom*
[2]*John Innes Centre, Norwich Research Park, Norwich, NR4 7UH, United Kingdom*
[3]*Fera Science Ltd, York Biotech Campus, Sand Hutton, York, YO41 1LZ, United Kingdom*
[4]*Mestrelab Research S.L., Avenida de Barcelona 7, Santiago de Compostela, Spain*

e-mail: Nathan.ONeill@uea.ac.uk

Introduction

Turmeric is the powdered rhizome of the *Curcuma Longa* plant and is used for culinary and medicinal purposes. As one of the **most common examples of spice adulteration**, turmeric fraud is facilitated by the complex and dispersed nature of the commodity's supply chains and is motivated by **economic opportunity**. Dyes such as lead chromate and metanil yellow, in addition to exogenous bulking agents, have been found adulterating commercial turmeric samples, presenting significant health risks.[1,2]

On-site colourimetric tests that are unreliable and do not screen for unknown entities are currently used to detect turmeric adulteration. Untargeted techniques such as **ATR-FTIR** have been used for food authenticity screening and **^{1}H NMR** is emerging as another untargeted approach. Since turmeric is composed of **~5% curcuminoids** (**Figure 1**) that produce distinct chemical markers for analysis, these analytical techniques can be proposed for turmeric authenticity analysis. However, the costs associated with high-field NMR render it unfavourable for many within the food industry whereas **benchtop NMR is cheaper and more accessible**.

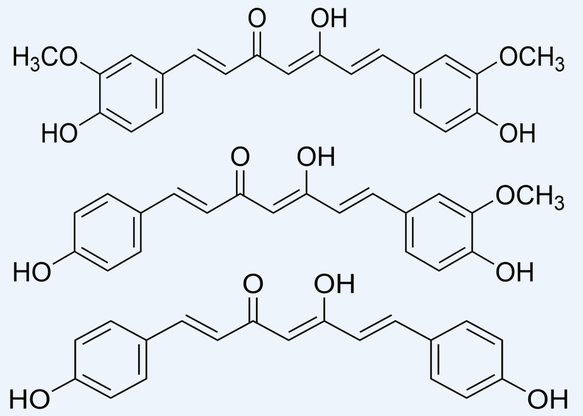

Figure 1: Structures of curcumin (top) , demethoxycurcumin (middle) , bisdemethoxycurcumin (bottom)

Objective

Currently, there are **no harmonised methods** for authentication, and this work addresses a key gap in the interest of food safety. Our **aim** is to evaluate the use of bench top analytical instrumentation as rapid authenticity screening approaches to turmeric fraud identification. For this, 77 samples (32 from a domestic online market and 45 from an overseas online market) of turmeric were analysed through ATR-FTIR and **benchtop 43 MHz ^{1}H NMR**. For ATR-FTIR, the samples were analysed in biological triplicate, yielding 231 spectra, and for 43 MHz ^{1}H NMR, the samples were analysed in biological and technical triplicate respectively, yielding 693 spectra. Chemometric analysis was performed on these spectra.

Results

1. Method optimisation

43 MHz ^{1}H NMR spectra were acquired using **ultrasonication-assisted extraction** in acetone-d6 and DMSO-d6. As shown in **Figure 2**, the acetone-d6 spectrum (left) illustrates greater peak resolution in the region of the aromatic curcuminoid protons (6-8 ppm), and a sharper curcuminoid methoxy singlet (3.9 ppm) that is more distinguishable from the water region than in DMSO-d6 (right). Based on these factors, **acetone-d6 was selected** as the solvent for all subsequent extractions for NMR spectral acquisition.

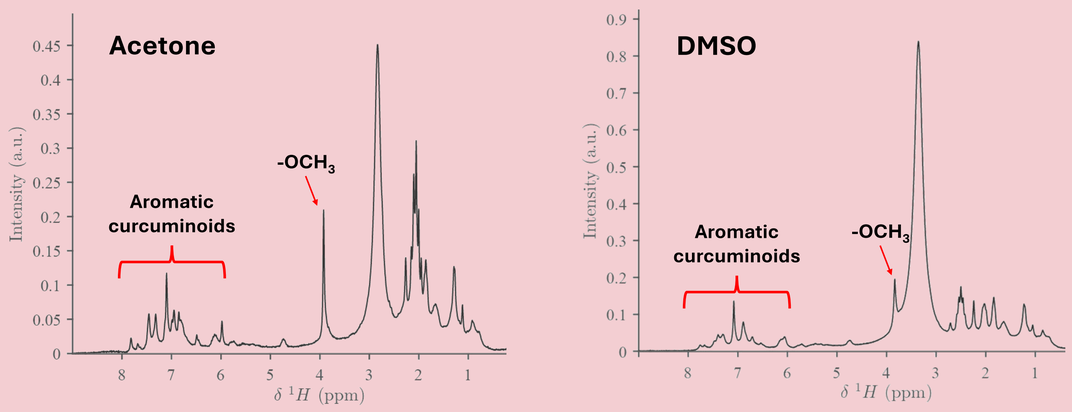

Figure 2: ^{1}H NMR spectrum of **turmeric extracted** in acetone-d6 (left) and DMSO-d6 (right). Spectra were acquired on the 43 MHz Magritek Spinsolve.

2. 43 MHz ^{1}H NMR

From the PCA plot (**Figure 3)**, several trends were observed. First, the **domestic turmeric samples** formed a relatively tight central cluster. Many of the **overseas turmeric samples** were distributed away from the central region. This indicated that some samples formed a **chemically distinct region**.

Tighter clustering was observed between biological triplicates, indicating a **high degree of reproducibility**, which suggested the protocol used was robust and yielded consistent results.

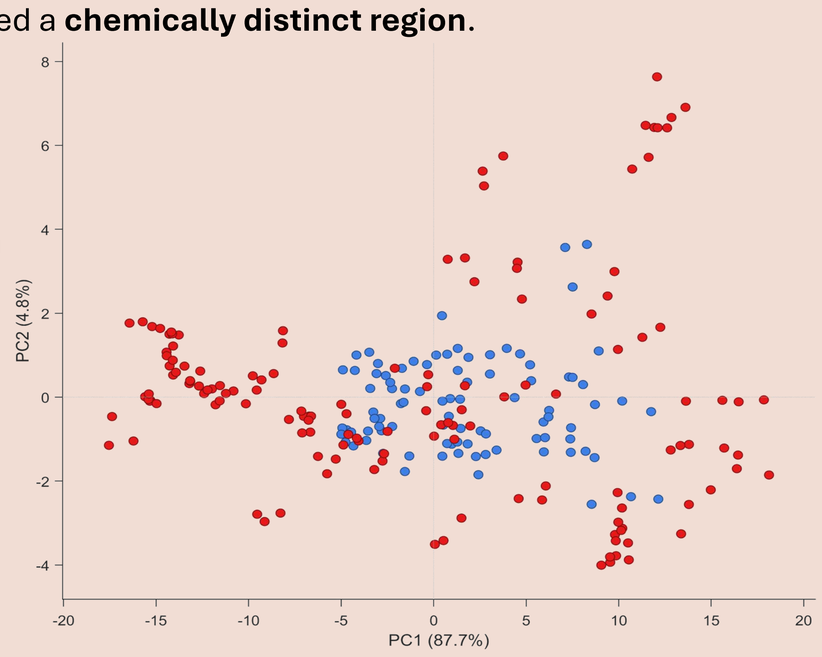

Figure 3: PCA scores plot for 77 turmeric samples analysed in biological triplicate *via* 43 MHz ^{1}H NMR. Domestic online samples are in **blue**, overseas online samples are in **red**.

3. ATR-FTIR

From the PCA plot (**Figure 4)**, the **domestic samples** again formed a tight central cluster, consistent with the grouping in the NMR scores plot (**Figure 3**). The **overseas outliers** in the FTIR analysis were also consistent with those in the NMR analysis. Strong **intra-sample reproducibility** was observed again between biological replicates.

By drawing the same conclusions from two independent untargeted analytical methods, there is likely meaningful chemical variation and grouping between both sample sets.

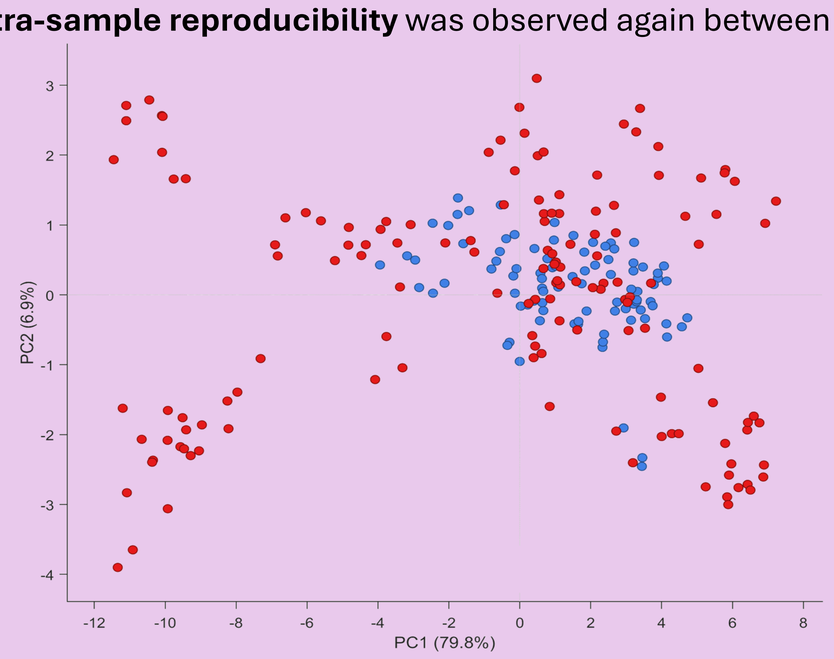

Figure 4: PCA scores plot for 77 turmeric samples analysed in biological triplicate via ATR-FTIR. Domestic online samples are in **blue**, overseas online samples are in **red**.

Conclusions and future directions

Current work: exploratory analysis

- Chemometric pipeline elucidated – regions of interest pinpointed and analysed for two methods.
- **Intra-sample reproducibility** observed.
- Complementarity exhibited between FTIR and NMR.
- **Little to no sample preparation** required.
- Cross-complementarity will be further demonstrated by data analysis such as **canonical correlation analysis.**

Next stage: diversifying & standardising methodology

- Benchtop mass spectrometry to be added to the workflow.
- This will allow more facile detection of inorganic adulterants.
- Once methods have been standardised, an **authentic reference database** will be constructed which encompasses natural variability.
- One-class classification approaches can then be used to detect genuine outliers.

Acknowledgements: I would like to thank the University of East Anglia and the Community for Analytical Measurement Science for funding this research.

References: [1]J. E. Forsyth *et. al.*, Sci. Total Environ., 2024, 949, 175003.
[2] S. Gafner *et. al.*, Pharm. Biol., 2025, 64, 87–107.