Institution: Queen's University, Belfast

Unit of Assessment: UoA6

Title of case study: Tackling fraud in the herb and spice sector using a fingerprinting approach

Period when the underpinning research was undertaken: 2010-2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor Chris Elliott	Professor of Food Safety	2006-present
Dr Simon Haughey	Senior Research Fellow	2008-present

Period when the claimed impact occurred: From 2014 – 2020

Is this case study continued from a case study submitted in 2014? No

Summary of the impact

Technological significance: Food fraud is widespread, costing >GBP20,000,000,000 per year. Herbs and spices have a global trade value of >USD3,000,000,000. The Queen's University team **developed the first fingerprinting approach to gain ISO accreditation for detection of adulteration**, which demonstrated that >25% of sold oregano was adulterated.

Industrial significance: This fingerprinting approach **detected adulterants in oregano in the UK, Norway and Australia.** Consequently, business practice changed globally with recognition of the value of identifying fraud.

Economic significance: A spin-out company, Cibus, providing services to detect adulteration was formed in 2020, creating four full-time posts and raising £570,000 in seed funding.

Underpinning research

Professor Elliott, Dr Haughey and team have spent over a decade researching the detection of economically motivated adulteration (EMA) of food **[3.1; 3.2].** Traditionally microscopy was used as the industry gold standard for the detection of EMA of dried herbs and spices. This methodology provided a non-quantitative result and requires highly experienced and skilled individuals capable of differentiating extraneous herbaceous matter present as adulterants. Prof Elliott's team have developed an innovative quantitative spectroscopy-based approach to supplement the microscopy method. They applied chemometrics (the statistical modelling of chemical data) to spectral data from Near Infrared Reflectance (NIR) and Raman spectroscopy to detect the adulteration of chilli powder with Sudan dye, a group 3 genotoxic carcinogen **[3.1]**.

Having confirmed the feasibility of this approach, the team investigated potential adulteration of oregano and paprika after concerns were raised from an industry source. They developed and validated a two-tier approach. In the first tier samples were screened using Fourier-

Transform Infrared spectroscopy (FTIR) coupled to data analysis using chemometrics **[3.2]**. The second tier used Liquid Chromatography High Resolution Mass spectrometry (LC-HRMS) to confirm the adulteration **[3.3]**. This approach demonstrated that the Tier 1 test was ~90% accurate and could be used as a screening tool for suspect samples, and that the Tier 2 method, which was 100% accurate, was suitable for use as a confirmatory tool. The team advanced the testing strategy by further refining the methodology. They developed a faster, lower cost Tier 2 test based on identification of biomarkers for purity and adulteration using low resolution mass spectrometry LCMS/MS. This new methodology presented very high selectivity and specificity, excellent linearity, and acceptable accuracy (intra-assay 92–113%, inter-assay 69–138%) and precision (CV < 20%). When compared with the previously established FTIR screening assay it also revealed a good correlation of both qualitative and quantitative results (R2 > 0.81) **[3.4]**.

To complement the laboratory tests, Professor Elliott, Dr Haughey and team explored the development of field-based testing for food adulteration. Using miniaturised near infrared detectors connected via Bluetooth to smartphones, they discovered that they could quickly detect adulteration directly where food was being manufactured and sold **[3.5]**. Chemometric models accessed through a phone app are stored in an iCloud to facilitate remote access from anywhere in the world. The team partnered with the United Nations joint IAEA/FAO division on these projects **[3.6]**.

References to the research (indicative maximum of six references)

3.1 Haughey SA, Galvin-King P, Ho Y-C, Bell SEJ, Elliott CT. 2015. The feasibility of using near infrared and Raman spectroscopic techniques to detect fraudulent adulteration of chili powders with Sudan dye. Food Control, 48, 75-83.

3.2 Galvin-King P, Haughey SA, Elliott CT. 2020. The Detection of Substitution Adulteration of Paprika with Spent Paprika by the Application of Molecular Spectroscopy Tools. Foods. 16;9(7):944.

3.3. Black C, Haughey SA, Chevallier OP, Galvin-King P, Elliott, CT. 2016. Comprehensive strategy to detect the fraudulent adulteration of herbs: The oregano approach. Food Chemistry. 210, 551-557.

3.4 Wielogorska E, Chevallier O, Black C, Galvin-King P, Delêtre M, Kelleher CT, Haughey SA, Elliott CT. 2018. Development of a comprehensive analytical platform for the detection and quantitation of food fraud using a biomarker approach. The oregano adulteration case study. Food Chemistry. 239, 32-39.

3.5. Teye E, Amuah CLY, McGrath T, Elliott C T. 2019. Innovative and rapid analysis for rice authenticity using hand-held NIR spectrometry and chemometrics. Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy. 217,147-154.

3.6. McGrath TF, Haughey SA, Islam M, Elliott CT. 2020. The Potential of Handheld near Infrared Spectroscopy to detect food adulteration: Results of a global, multi-instrument inter laboratory study. Food Chemistry. 128718.

Details of the impact

Food fraud in its entirety is estimated to cost >GBP20,000,000,000 per year globally due to factors such as increased market competition and reputation loss **[5.1].** The global Herb and Spice supply chain trade was valued at over USD21,500,000,000 billion in 2018 and is predicted to reach USD25,000,000,000 by 2025 **[5.2]**.

The team's success in detecting adulteration in chilli powder **[3.1]** led to British Pepper and Spice (BPS), a leading UK retailer of dried herbs and spice, approaching the team in 2014 with concerns over the authenticity of herbs entering the market from Turkey **[5.3]**. BPS supply bulk quantities to the broader food manufacturing industry in the UK and Ireland and had long suspected the adulteration of Turkish herbs, namely sage and oregano, with other much cheaper herbaceous materials. The company felt their market share had been reduced and that there was an increasingly rapid deterioration in the authenticity and, therefore, quality of Turkish dried herbs on sale in the UK and Irish markets **[5.3].** To put this into global context, Turkey is a major exporter of herbs and spices, with Turkey's herb and spice industry currently being worth USD850,000,000 **[5.4].** BPS, in partnership with WHICH? consumer magazine, then commissioned Professor Elliott, Dr Haughey and team to conduct a survey of oregano on sale in retail and food service sectors of the UK and Irish markets. In response to the request for assistance, Professor Elliott's team employed their two tier fingerprinting technique to test for and identify adulterants. The results demonstrated that >25% of all retail and food service packs of oregano sold in the UK and Irish markets were adulterated **[3.4, 5.5].** Therefore, the pioneering work of Professor Elliott, Dr Haughey and his was central to the detection of adulteration in Turkish herbs **[3.3, 3.4, 5.3].**

In response to this ground-breaking industry collaboration, British Pepper and Spice (2006 – 2018) stated:

"*Working with Elliott and his team British Pepper and Spice supported the development of the spectroscopy-based technique which has proven to be invaluable as an accurate and quantitative method. The work carried out by his department is recognised throughout the global dried herb and spice sector as having enabled there to be a step change in supply chain controls and acted as a deterrent to the perpetrators of adulteration."* **[5.3]**

Altuntas Baharat, a major Turkish supplier of herbs also confirmed:

"*Following on from the ground breaking research by Queen's University Belfast and specifically the Institute for Global Food Security to develop definitive methods of analysis to*

identify adulterants in oregano and sage we have seen a step change in our industry and a growth in our business…Your research has had a truly global reach and we have seen benefits in markets as diverse as Japan, USA, Australia and of course Europe." **[5.6]**

The food fingerprinting approach developed by Professor Elliott, Dr Haughey and team has consequently, not only been instrumental in the detection of international food fraud, but has benefited suppliers nationally and internationally and helped restore consumer confidence in the industry.

After publication of the WHICH? survey results **[5.5],** upwards of fifty of the major UK and Irish food manufacturers and retailers began a large scale programme of testing raw materials and finished products, throughout their supply chains, using the new test developed at QUB. One retailer (Sainsbury's) went so far as to declare an amnesty for any supplier found to be the victim of food fraud **[5.7].** In 2018, six of the UK's largest retailers offered an amnesty to their suppliers in terms of using adulterated herbs and spices. They were instructed to send samples to QUB for testing. This exercise was undertaken and many issues were uncovered and dealt with under secrecy agreements with suppliers **[5.7].** In 2020, the world's largest herb and spice company, McCormick's (relevant products sold under Schwartz brand in UK) instructed their entire supply base to have their products tested for authenticity at QUB under Prof Elliott's supervision **[5.8]**. The same adulteration issue was found to exist in multiple markets for example in Australia and Norway, which resulted in the prosecution of Spencers foods based in Australia **[5.9].**

As a consequence of this research the QUB Asset Technology Centre became the world's first accredited laboratory for the detection of herb and spice adulteration using a non-targeted molecular spectroscopy method (UKAS ISO 17025) **[5.10]**. The team were also recently given the status of UK Centre for expertise in food authenticity by the UK government, the only university to hold this status. This research also resulted in the formation of a QUB spin-out company, Cibus (recently re-named to Bia analytical, but referred to as Cibus throughout this document to avoid confusion), which is dedicated to the testing of herbs and spices globally. It was set up with a grant (GBP210,000) from Innovate UK, with substantial further investment (~GBP400,000) secured from business angels in partnership with a FTSE100 listed company (Halma). The company created 4 full time highly skilled posts at start up **[5.11]**. The success of Professor Elliott and his team has also resulted in IGFS being awarded the status of 'An International Atomic Energy Agency Collaborating Centre' in December 2020. The award was made based on scientific excellence and support given to IAEA in the fields of food safety, authenticity and traceability.

Sources to corroborate the impact (indicative maximum of 10 references)

5.1 Galvin-King P, Haughey SA, Elliott CT. (2018). Herb and spice fraud; the drivers, challenges and detection. Food Control, 88, 85-97.

5.2 Seasonings Market Report
https://www.gminsights.com/industry-analysis/seasonings-market

5.3 Testimonial from the British Pepper and Spice company

5.4 Value of Turkey's herb and spice industry

https://www.freshplaza.com/article/2149771/turkey-s-850-million-herbs-and-spices-export-potential/

5.5. Which? Magazine (2013) Does your spice rack contain fake oregano? https://www.which.co.uk/news/2015/07/does-your-spice-rack-contain-fake-oregano-408737/

5.6 Testimonial from Altuntas

5.7. Testimonial from Sainsbury's

5.8. Testimonial from McCormick's

5.9. Spencer Foods prosecution evidence
https://www.accc.gov.au/system/files/public-registers/undertaking/1200238-1-Oregano%20-%20Anchor%20Foods%20-%20signed%2015%20December%202016.PDF
File also attached.

5.10 ISO 17025 certificate for UKAS accreditation of molecular spectroscopic testing of herbs for authenticity in the ASSET Technology Centre in the Institute of Global Food Security led by Professor Chris Elliott.

5.11 Cibus spin out company seed funding evidence
https://www.irishnews.com/business/2020/04/08/news/cibus-raises-570-000-seed-funding-in-fight-to-stop-food-fraud-1895877/