Institution: Queen's University Belfast

Unit of Assessment: 6 - Agriculture, Veterinary and Food Science

Title of case study: Protecting the Integrity of the Global Feed-Food Supply Chain: Detecting and Preventing Chemical Contamination

1. Summary of the impact (indicative maximum 100 words)

This research has culminated in a unique risk-based collaborative system enabling industry to prevent supply chain contamination. Elliott's team leads international work developing and implementing innovative methods to detect multiple chemical contaminants in food and feed, one of the greatest challenges facing industry and regulators worldwide due to global supply chains. Elliott's research resulted in the worldwide implementation of multiple ISO accredited procedures; detection systems based on this research are sold in >50 countries. The outcomes include enhanced protection of consumer health, greater business income and improved reputations of industry and regulators globally. Licensing/royalties streams support translational research in the Institute (~£200,000).

2. Underpinning research (indicative maximum 500 words)

The contamination of foods across the world by a multitude of different chemicals such as drugs (1), pesticides, heavy metals and mycotoxins has resulted in many food scares, poisoning episodes, massive economic costs and a general loss of consumer trust in the integrity of the food we eat. European legislation introduced in the 1990's (EC/96/22 and EC/96/23) set out standards that had to be reached by member states to control chemical contamination of the feed-food supply chain. Elliott and his colleagues set out to produce two types of testing procedures that would support the implementation of these directives and protect the consumer.

Problems addressed included the isolation of many and differing compounds from highly complex matrices, unequivocal identification to forensic standards and quantification at parts per billion concentrations with acceptable measurement uncertainty. Some compounds, owing to their toxicity and significance to the consumer, were designated as 'zero-tolerance' in law, presenting industry and regulators with the huge problem of interpreting that concept in the real world of measurement science.

The QUB team has become renowned globally for their work in developing rapid, broad-spectrum antibody-based screening tests for chemicals in feed and foods. They developed innovative chemistries that permitted the generation of antibodies that could detect entire families of chemicals with unprecedented levels of sensitivity. These antibodies were then incorporated into a range of immunochemical platform technologies that provided a multitude of end users with rapid and reliable results. QUB pioneered the use of surface plasmon resonance biosensing for contaminants (2,4,5). This was achieved by developing a series of novel surface chemistries on gold sensor surfaces that permitted antibody–chemical interactions to be measured in minutes as opposed to up to a day for conventional tests. Another notable innovation was the very simple, low cost and rapid sample preparation techniques developed. The innovations also included the use of purified cell receptors to detect families of chemical contaminants. The ability to extract and stabilise the beta-agonist receptor from cultured cells allowed the only receptor-based test in the world to detect man-made chemicals to be introduced into European monitoring programmes (3). European legislation also demanded that advanced mass spectrometric techniques had to be used to produce 'unequivocal evidence' of the presence of chemical contaminants in feeds and foods. Elliott and his group not only developed such methods but took these further than many other research groups around the world by producing methods that could confirm the presence of multiple contaminants using highly innovative forms of sample preparation and chromatography (6). The extreme robustness built into these methods, coupled to their ultra-high sensitivity and rigorous validations, enabled them to be used in regulatory laboratories around the world. There are over 100 peer-reviewed publications related to this case study. The opportunities opened up by the research included safer global trade, but most significantly a novel system of business

collaboration for supply chain integrity underpinned by the research institute as the 'honest broker'.

3. References to the research (indicative maximum of six references)

1. Elliott CT, Thompson CS, Arts CJM, et al. (1998) Screening and confirmatory determination of ractopamine residues in calves treated with growth promoting doses of the beta-agonist. Analyst 123: 1103-1107.
2. Traynor IM, Crooks SRH, Bowers J, Elliott CT (2003) Detection of multi-β-agonist residues in liver matrix by use of a surface plasma resonance biosensor Analytica Chimica Acta 483: 187-191.
3. Nielen MWF, Elliott CT, et al. (2003) Identification of an unknown beta-agonist in feed by liquid chromatography/bioassay/quadrupole time-of-flight tandem mass spectrometry. Rapid Communications in Mass Spec 17: 1633-1641.
4. Ferguson J, Baxter A, Young P, Elliott CT, et al. (2005) Detection of chloramphenicol and chloramphenicol glucuronide residues in poultry muscle, honey, prawn and milk using a surface plasmon resonance biosensor and Qflex(R) kit chloramphenicol. Analytica Chimica Acta 529: 109-113.
5. Dumont V, Huet A-C, Traynor I, Elliott C, et al. (2006) A surface plasmon resonance biosensor assay for the simultaneous determination of thiamphenicol, florefenicol, florefenicol amine and chloramphenicol residues in shrimps. Analytica Chimica Acta 567: 179-183.
6. Malone EM, Dowling G, Elliott CT et al. (2009) Development of a rapid, multi-class method for the confirmatory analysis of anti-inflammatory drugs in bovine milk using liquid chromatography tandem mass spectrometry. Journal of Chromatography A 1216: 8132-8140.

Supporting Grants

Foodsense (1999-2001) Sponsor EU FP4, PI Prof Chris Elliott (QUB), award to QUB £178,000
Glucocorticoids (2000-2003) Sponsor EU FP5, PI Prof Chris Elliott (QUB), award to QUB £180,000
Feedstuff Radius (2001-2004) Sponsor EU FP5, PI Prof Chris Elliott (QUB), award to QUB £263,000
Biocop (2005-2010) Sponsor EU FP5, PI Prof Chris Elliott (QUB), award to QUB £1,445,000
Conffidence (2009-2012) Sponsor EU FP7, PI Prof Chris Elliott (QUB), award to QUB £320,000
QSAFFE (2011-2014) Sponsor EU FP7, PI Prof Chris Elliott (QUB), award to QUB £446,000
Demoncheck (2008-2011) Sponsor Invest NI PI Prof Chris Elliott (QUB), award to QUB £248,000
Feedcheck (2011-2013) Sponsor Invest NI PI Prof Chris Elliott (QUB), award to QUB £198,000

4. Details of the impact (indicative maximum 750 words)

The implementation of batteries of innovative tests, developed by Elliott and his colleagues, in the control programmes of regulatory laboratories around the world has had a major impact through the protection of consumers globally and enhancement of trading opportunities. Without such tests many contamination incidents would go unchecked and the ability of many countries to monitor imported foods and support their own exports would be greatly inhibited.

The globalisation of the trade in animal feeds and food has brought about many benefits, e.g. cost reduction and year round availability of foodstuffs. However, one of the biggest problems it has caused is a massive increase in the importation of multiple products into Europe from countries with low standards of feed/food safety. Since the BSE crisis of the 1980's European consumers have become more and more concerned with the safety of the food they eat. This has led to a marked reduction in their trust in governments' ability to protect them from food-related hazards. Among the most feared risks are those relating to dangerous chemicals in food. There are several thousand licensed veterinary pharmaceuticals and pesticides and many hundreds of illegally used compounds. Added to this are the problems with dioxin/PCB contaminations, heavy metals, mycotoxins and fraud issues involving nitrogen substitutes (such as melamine). An additional complexity is that these chemicals must be measured at very low concentrations to meet legislative requirements (usually parts per billion). The time to undertake the analysis and costs involved add a further dimension of difficulty to contaminant analysis/detection. During a period spanning nearly 20 years Elliott's work at QUB in delivering methods that met, and continue to meet, ever-

increasing demands has become recognised globally. The majority of laboratories around the world, both private sector and governmental, employ at least a number of these tests in their routine testing programmes. The global sales of diagnostic test kits plus verification from a number of leading governmental monitoring laboratories helps reinforce this claim. Elliott and colleagues have organised many training workshops for scientists working in regulatory environments from all over the world to learn the QUB procedures. These have been performed in conjunction with the EU Community Reference Laboratories for Drug Residue Control, the EU Directorate Generals SANCO (Food Safety) and DG TRADE. In addition, in collaboration with the UN FAO, training workshops organised across the developing world have achieved global reach. In 2001 QUB (Elliott) was a founding member of the international School for Advanced Residue Analysis in Foods (http://www.saraf-educ.org/). This international School, held twice annually, has trained over 600 scientists from 90 countries in methods developed at QUB. In 2010 this initiative was extended from funding from the Marie Curie programme to develop training opportunities specifically for European postgraduate students.

The development of easy to use and reliable ELISA and biosensor-based test kits for the detection of drug residues in foods has been another excellent means of transferring the research to food control laboratories globally. Kit sales now extend to well over 50 countries around the world (2013 data). Indeed new product lines are being developed in collaboration with QUB via funding for postgraduate students, many of whom get jobs working in the associated diagnostics companies (some via KTP projects) upon completion of their degrees. Tests to detect illegal dyes, antibiotics and toxins in foods were launched in 2012 by Neogen.

Good testing methods alone are not sufficient to prevent feed and food contamination. The costs associated with developing and implementing robust monitoring programmes are substantial. It is impossible to test every batch of animal feed and foodstuff produced for every possible contaminant that might be present. Elliott and his team undertook one of the largest studies of its kind in the world. They analysed every reported chemical-based food contamination incident recorded globally over a 5-year period. From this they were able to determine frequency of events relating to the types of feed and food commodities, the geographic origin of the contaminated materials and the possible health risks and industry risks associated with each contamination event. Using a set of algorithms and intimate knowledge of chemical analytical techniques, Elliott produced a scheme for industry to set up a self-monitoring programme. This unique scheme was implemented in 2013 in Northern Ireland by the Grain Trade Association as a pilot and will be rolled out to the rest of Ireland and the UK in 2014. Other global regions are using the QUB model to develop much more robust national monitoring programmes.

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

1. A breakdown of funding received by QUB from kit sales, and listing of countries kits are sold in by biopharm and EuroProxima (2008-2012 data).
2. Letters from heads of various drug control laboratories (UK, Ireland, France, Holland) indicating that methods developed by QUB have been implemented into their national control programmes.
3. Letter from Dutch government official to state that QUB research is frequently cited in national court cases relating to the misuse of veterinary drugs.
4. Chairman of the Northern Ireland Grain Trade Association (NIGTA) about the important role QUB has played in developing the world's best quality assurance scheme for feed.