

Institution: Harper Adams University (HAU)		
Unit of Assessment: UoA6		
Title of case study: Fresh produce food safety: reducing <i>E. coli</i> contamination on leafy salad crops in the UK and overseas.		
Period when the underpinning research was undertaken: 2006 - 2015		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): James Malcolm Monaghan	Role(s) (e.g. job title): Professor	Period(s) employed by submitting HEI: 2005-
Period when the claimed impact occurred: 2013-2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact (indicative maximum 100 words) <p>This case study describes how research into contamination risks for leafy salads and subsequent persistence of foodborne illness organisms, e.g. <i>E. coli</i>, led to production of industry focussed resources, namely:</p> <ul style="list-style-type: none"> • Web-based risk assessment tools for irrigation water, manure use and worker hygiene • Factsheet on managing microbial contamination risks • Formal industry guide to watercress production. <p>These are key resources used by fresh produce businesses to develop robust food safety management systems that comply with legal and commercial standards within UK and international supply chains. This has been linked to a direct benefit to consumers through avoidance of illness, hospitalisation and prevention of deaths.</p>		
2. Underpinning research (indicative maximum 500 words) <p>Pathogenic <i>E. coli</i> (e.g. O157:H7, O104:H4) outbreaks have frequently been linked with consumption of lettuce and leafy greens. These outbreaks have led to hospitalisation and deaths and consequently reduced consumption of implicated crops. The underpinning research described here:</p> <ul style="list-style-type: none"> • assessed production practices; • quantified the risks of contaminating crops under normal growing conditions and the persistence of microbial contamination under the same conditions; • evaluated the efficacy of interventions (such as hygiene practices) that should be implemented by primary producers. <p>The studies were funded by the Agriculture and Horticulture Development Board (AHDB) and the Food Standards Agency (FSA)^{3,1-3,5}, and the International Life Science Institute (ILSI)^{3,6}.</p> <p><u>Irrigation: quantifying its pathogen contamination risk</u></p> <p>The programme of work started with an FSA funded review that highlighted that growers required guidance on microbial food safety and undertaking microbial risk assessments</p>		

(RA)^{3.1}. Consequently, the AHDB funded a programme of research to quantify the risk of pathogen contamination through irrigation water. The work was innovative, moving theoretical lab-based approaches into commercially relevant field conditions. For the first time in temperate conditions, the distribution and decline of non-pathogenic microbes were quantified over the growing season in the soil and on the leaf surface of leafy salad crops^{3.2}.

The study also looked at the role of irrigation systems, in reducing the risk of contamination and the distribution of bacteria through soil splash. This work was of international relevance and quantified, for the first-time, soil splash as a vector of potential microbial contamination in field production^{3.3}.

Direct handling of produce: establishing cause of a foodborne illness outbreak

The subsequent FSA research was in response to a UK outbreak of verocytotoxigenic *E. coli* (VTEC) O157 in 2011 that was linked to domestic preparation of unwrapped leeks, or potatoes bought in paper sacks. The study quantified the persistence of faecal contamination on workers' hands and quantified, for the first time, the transfer of microbial contamination to a root crop through direct handling. The efficacy of a number of handwashing approaches was also studied^{3.4}.

Crops were grown at HAU following standard commercial practice and a marker for *E. coli* O157 (nontoxigenic *E. coli* O145) was applied, in slurry and irrigation water, to the crops. The persistence of the marker was quantified through processing and simulated supply chain conditions and avoided the issues that can arise from using lab adapted strains of markers^{3.5}. The work established that it was plausible that the cause of a foodborne outbreak involving *E. coli* O157, in 2011, was soil contamination carried through the supply chain and into the domestic kitchen^{3.5}.

Developing international guidance on microbial risk assessment for leafy vegetables

As a consequence of this research, Monaghan was invited on to the ILSI Europe - Risk Analysis in Microbiology Expert Group (2013-16) to develop a formal RA framework for primary producers of leafy vegetables^{3.6}. The scope of the study was to develop internationally relevant guidance, and the membership of the expert group reflected this with members from France, Netherlands and UK. The work was then publicised by the International Association of Food Protection (IAFP) through an international (US and Europe) webinar and invited presentations at IAFP meetings in Greece and Sweden.

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

3.1 **Monaghan JM**, Thomas DJI, Goodburn K and Hutchison ML (2008) A review of the published literature describing foodborne illness outbreaks associated with ready to eat fresh produce and an overview of current UK fresh produce farming practices. Final report on FSA project B17007, 230 pp.

3.2 Hutchison M L, Avery S M and **Monaghan JM** (2008) The air-borne distribution of zoonotic agents from livestock waste spreading and microbiological risk to fresh produce from contaminated irrigation sources. *J. Appl. Microbiol.* 105:848-857

3.3 **Monaghan JM**, Hutchison M L (2012) Distribution and decline of human pathogenic bacteria in soil after application in irrigation water and the potential for soil-splash mediated dispersal onto fresh produce. *J. Appl. Microbiol.* 112:1007–1019

3.4 **Monaghan JM** and Hutchison ML (2016) Ineffective hand washing and the contamination of carrots after using a field latrine. *Letters in Applied Microbiology* 62: 299–303

3.5 Hutchison M L, Harrison D, Heath JF and **Monaghan JM** (2017) Fate of *Escherichia coli* O145 present naturally in bovine slurry applied to vegetables before harvest, after washing and storage under simulated wholesale- and retail- distribution conditions. *J. Appl. Microbiol.* 123: 1597–1606

3.6 **Monaghan JM**, Augustin JC, Bassett J, Betts R, Pourkomaillian B, Zwietering MH (2017) Risk assessment or assessment of risk? Developing an evidence-based approach for primary producers of leafy vegetables to assess and manage microbial risks *Journal of Food Protection* 80(5):725-733

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

Foodborne outbreaks associated with fresh produce are mainly caused by bacterial zoonoses, including pathogenic *E. coli* and are a serious problem, therefore managing microbial food safety in fresh produce is a key focus in the agri-food industry. Risk Assessment (RA) and Good Agricultural Practice (GAP) are essential components of industry-led food safety management systems, such as Red Tractor Farm Assurance and GlobalGAP (the worldwide standard for GAP), and are a legal requirement of Regulation (EC) No 852/2004 on the hygiene of foodstuffs.

The research described in Section 2 has produced impact in two major ways:

- firstly, by advising the UK fresh produce industry on GAP to reduce microbial contamination.
- secondly, by providing guidance on microbial risk assessment to assess the contamination risks from water, manure and worker hygiene.

a) Advising UK fresh produce industry on GAP to reduce microbial contamination

i. First fresh produce guidelines written and incorporated into UK standards

Monaghan & Hutchison were commissioned by AHDB and FSA to establish guidelines to manage microbial contamination and to disseminate these through a factsheet, aimed at commercial growers and the wider supply chain^{5.1}. The factsheet summarised the different microbial hazards, the contamination routes through which they can contaminate crops, the best practices to minimise these contamination events and the monitoring of inputs and crops that can be used. Research and results from Ref 3.2 and Ref 3.3 were incorporated into the guidelines/factsheet which was published in 2010.

The launch of the factsheet was supported by nine roadshows delivered by Monaghan around the UK to publicise the factsheet. These events were attended by key growers from the major high-risk crop producers in all four UK nations.

Comprehensive, practical guidelines were needed by the industry. When released, the fresh produce sector was coming under pressure from the retail supply chain to manage microbial contamination following a high-profile *E. coli* O157 outbreak linked to salads in the USA. The factsheet was the first comprehensive material in the UK targeted at growers^{5.2} and was written in a manner that provided practical guidance to mitigate risks^{5.3}.

The impact of the factsheet was significant. Commercial businesses incorporated the guidance into their own food safety procedures^{5.2, 5.3, 5.4}. The information in the factsheet was incorporated into the Red Tractor Farm Assurance standards used by the whole industry^{5.2, 5.4} and, importantly, when being audited against Red Tractor standards. This demonstrated that the access and use of the factsheet by a grower is accepted as evidence of compliance to specific audit points^{5.2}. Critically, this work “has had direct benefits for consumers and wider society through avoidance of illness and hospitalisation and prevention of deaths in high-risk groups”^{5.4}.

ii. First watercress good hygiene guide produced and successfully applied

Monaghan was also commissioned by FSA to author the first *Industry Guide to Good Hygiene Practice: Watercress* providing information on legal obligations for producers and what their compliance with food hygiene law. Results from Monaghan's research^{3.2, 3.4, 3.6} were incorporated into the guidance, and were applied as follows.

- Official recognition by the FSA and Food Standards Scotland (FSS) and subsequent compliance with the relevant legislation^{5.5}. Nearly all watercress growers, both small- and large-scale businesses now follow the industry guide. No foodborne illness outbreaks linked to UK grown watercress have occurred since the guide was introduced.
- Implementation of recommendations from the Industry Guide by UK watercress growers for crops grown in Spain and Portugal within these international supply chains^{5.6}.

b) Providing first guidance tool on microbial RA for water, manure and worker hygiene

Monaghan & Hutchison were also commissioned by AHDB/FSA to develop a web-based Risk Assessment tool for fresh produce growers which was released in 2010, and revised in 2014, 2018 and 2021^{5.7}. The tool consists of a matrix of questions that the grower completes and moves through the RA process. At each question there is also a brief rationale and links to detailed grower accessible evidence, summarised from the research^{3.2, 3.3} and later Ref 3.4, 3.5 & 3.6. This was the first industry-wide RA tool developed in the UK, and the FSA, FSS and Red Tractor all promote using the web tool as best practice^{5.8}.

Compliance with Red Tractor Fresh Produce grower standards is mandatory in all UK major retailers and the standards are followed by approximately 2,500 growers representing greater than 90% of UK growers. Uptake has been high as the tool is readily accessible and enables risk management in areas where grower expertise is limited^{5.4} and provided step by step ways to mitigate the risks in a way that farming businesses could accommodate and adapt to^{5.3}.

In the last 3 years the RA tool has been used for 4,676 individual assessments.

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

5.1 Monaghan JM and Hutchison ML (2010) *Monitoring microbial food safety of fresh produce*. FSA/HDC Factsheet 13/10. 16pp.

5.2 Letter from D Kennedy (Technical Director JepCo & Chair of RTFP Technical Advisory Committee)

5.3 Letter from H Mowatt (Director of Safety and Compliance Wm Morrisons)

5.4 Letter from Ed Moorhouse (Independent Consultant, Ex Technical Director G's)

5.5 Monaghan JM (2017) *Industry Guide to Good Hygiene Practice: Watercress*. FSA/FSS. pp43.

5.6 Letter from Steve Rothwell (Ex Technical Director Vitacress)

5.7 Web-based risk assessment tool for fresh produce growers (2010; rev 2014, 2018 & 2021). <http://freshproducetool.foodstandards.gov.scot/>

5.8 Red Tractor Fresh Produce guidance linking to webtool;
https://assurance.redtractor.org.uk/contentfiles/Farmers-7058.pdf?_id=637311856137223163
<http://freshproducetool.foodstandards.gov.scot/>