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Integration of computational tools, data analysis and social science into food safety risk assessment

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Abstract

The EU-FORA Fellowship Programme 'Integration of tools and social science into food safety risk assessments' was proposed by the Food Standards Agency (FSA), the government department responsible for food safety in the UK. The working programme was organised into four modules, covering different areas of risk assessment, including microbiological risk assessment, chemical risk assessment, exposure assessment, risk prioritisation and the integration of risk assessment with social science. During this period, the fellow had the unique opportunity to gain experience in different fields of risk assessment, namely how to conduct a systematic review, to assess the risk of microbiological and chemical hazards, to make use of modelling tools for exposure assessment and risk prioritisation, to write scientific reports for committees and networks at the national level and to understand the role of social science in risk assessment. In addition, the fellow was able to attend several meetings, seminars, courses and workshops that helped him to gain further insight in the field of food science. The complete programme enabled a fast learning curve that allowed the fellow to have an overview of the different tools that can be employed in the wide field of food safety risk assessment, in order to acquire skills and competences that can be used in his future career.

Keywords: modelling, risk assessment, systematic review, mycotoxins, social science

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1. Introduction

The fellow was enrolled in the EU-FORA fellowship programme working on the project 'Integration of tools and social science into food safety risk assessments' at the Food Standards Agency (FSA) in London. The FSA is an independent UK Government department that works across England, Wales and Northern Ireland to protect public health and consumers' wider interests in relation to food. Risk assessment at FSA is organised in teams, including Microbiological Risk Assessment (MRA), Chemical Risk Assessment (CRA), Exposure Assessment Team (EAT) and Regulated Products, all of which belong to the Risk Assessment Unit (RAU). The RAU is embedded within the Science, Evidence and Research Directorate (SERD), which also comprises the Analytics Unit (AU), which includes statisticians, economists and social scientists. The different units actively interact in an interdisciplinary environment forming virtual teams for specific work areas. The work carried out at FSA is supported by Scientific Advisory Committees (SACs), which are independent committees and working groups comprised of scientists, practitioners, medics and academics. The function of a SAC is to help FSA access, interpret and understand the full range of relevant scientific information and to make judgements about its relevance, potential and application. There are multiple SACs in the UK associated with food safety, including the Committee on Toxicity (COT), Committee on Carcinogenicity (COC), Committee on Mutagenicity (COM), Scientific Advisory Committee on Nutrition (SACN) and the Advisory Committee on the Microbiological Safety of Food (ACMSF). In addition, there are networks where the different UK departments discuss and share information about risk and risk prioritisation, such as the Human-Animal Infections and Risk Surveillance Group (HAIRS), Veterinary Risk Group (VRG) and Epidemiology of Foodborne Infections Group (EFIG).

The programme proposed for the EU-FORA fellow was tailored to provide an overview on the activities carried out within SERD, focusing on the different areas of food safety risk assessment and the interaction between risk assessment and social science. In addition, during his period at the FSA, the fellow was invited to attend a series of trainings, workshops, seminars and meetings, including meetings of the SACs, Strategic Surveillance and UK Risk Network, providing a complete spectrum of knowledge within the field of food safety risk assessment and the work carried out at FSA. The fellow was also involved in the 'Food for Thought' seminars, targeting innovative food science research projects, and 'Risky Bites', an informal lunch club which encourages the transfer of risk assessment methods. At the end of the programme, the fellow was also invited to give a presentation at a Risky Bites on his EU-FORA experience. To allow the fellow to work on the different areas of food safety at FSA, the EU-FORA Programme was split into four modules. Each module was coordinated by a co-supervisor and deputies, whose role was to follow progress and to arrange meetings and training for the fellow.

For the first module, the fellow was placed within the MRA team. His first task was to review the tools available to complete systematic reviews in the field of food risk assessment, including tools that apply machine learning and artificial intelligence methods, and to provide guidance to the unit. In addition, the fellow performed a systematic review on the prevalence of methicillin-resistant *Staphylococcus aureus* (MRSA) in recent years in Italy and reported the results in the form of a manuscript. The fellow was also trained on rapid risk assessment for food incidents and outbreaks, which is the everyday work of the unit. The final task of the module consisted of an introduction to the various tools used in the unit for the organisation of the workflow and the coordination of research projects.

The aim of the second module was for the fellow to gain a better understanding of the work of the CRA and the EAT at FSA. For this reason, the fellow was placed within the CRA team for 3 months. During this period, he was trained on using the tools available to undertake a quantitative exposure assessment and the use of data from national dietary surveys for carrying out bespoke exposure assessments. He was also trained on carrying out rapid risk assessments for chemical hazards and provided with realistic examples of toxicological incidents to assess and guide the drafting of risk assessments. The fellow was given a topic on which he had to draft a longer risk assessment to present to the COT, with guidance from scientific officers from the CRA and EAT. This provided the fellow with a good knowledge of the processes involved in the presentation and discussion of scientific reports submitted to the national committees.

In the third module, the fellow had the opportunity to work closely with the social science team at FSA. The main objective of this module was for the fellow to comprehend the interconnection between food risk assessment and social science, with a particular focus on public risk perception. This is crucial for understanding the psychological and social factors influencing the public when providing an expert

judgement, therefore affecting the interpretation of the overall risk analysis process. For this reason, the fellow reviewed the literature on the mental models affecting the risk perception of lay people and the biases associated with expert judgement and drafted a report on the topic.

The fourth and final module allowed the fellow to become more familiar with the on-farm stage of the farm-to-consumption risk assessment process, as well as attending meetings on risk prioritisation for pathogens of animal health importance. For this task the fellow was placed at the Animal and Plant Health Agency (APHA), where he applied sensitivity analyses to the results of a quantitative microbial risk assessment (QMRA) model to assess the transmission of ESBL-producing *Escherichia coli* on commercial pig farms. The fellow also had the chance to attend the meetings of SACs and different networks by which the UK government departments discuss the prioritisation of risk and share information related to risk, such as HAIRS and ACMSF.

2. Description of the work programme

2.1. Aims

The modules were organised in tasks and deliverables, targeting the main topics and activities of the specific area.

- Module 1: Investigation of the tools to complete a systematic review and development of food incident rapid risk assessment on microbiological hazards
- Module 2: Review of the tools used for exposure assessment and development of a risk assessment on a chemical hazard within the Toxicology team
- Module 3: Understanding the role of social science in risk assessment, with a focus on the mental models of the public and the expert judgement
- Module 4: Computational tools for the risk prioritisation and risk networks in the UK

2.2. Activities

2.2.1. Module 1

For the first module of the EU-FORA fellowship, the fellow was placed in the MRA team who deliver the national food safety risk assessment function for microbiological, prion and physical hazards. The MRA team also acts as the Secretariat to the ACMSF. The main task and deliverable for the EU-FORA programme consisted of a review of the tools and software available for carrying out a systematic review on a specific topic concerning a microbiological hazard, with reference to making use of machine learning techniques. Systematic reviews are a type of literature review used to identify, evaluate and synthesize the findings using systematic and reproducible methods (Grant and Booth, 2009, Jaspers et al., 2018). Machine learning techniques can provide excellent help for carrying out a broad systematic review, especially for the phases of title and abstract screening. The EFSA machine learning tool for systematic review (EFSA 2015, Jaspers et al., 2018) was tested by the fellow. The fellow then produced guidelines for using the tool and organised a training session for the MRA team.

The programme also included practical training on the process of conducting systematic reviews (Grant and Booth, 2009). For this reason, the fellow had to produce a review on a relevant microbiological hazard, which was chosen in the field of antimicrobial resistance (AMR); an emerging and global concern for both animals and humans (ECDC 2018, EFSA and ECDC 2019). Specifically, the fellow drafted a manuscript on the prevalence of MRSA in recent years in Italy, where MRSA infection in humans is one of the highest in Europe (ECDC 2018). The fellow carried out the literature search and screened the papers retrieved according to three review questions; i) targeting the epidemiology and characteristics of MRSA, ii) the prevalence of MRSA in livestock and humans in Italy and iii) advances in effective antimicrobials to use against MRSA. The papers selected were then analysed by the fellow in order to extract the relevant information and data, which were reported in the form of a manuscript that was presented and discussed within the MRA team.

Furthermore, training was provided in the field of microbiological food incident rapid risk assessment. MRA, and in particular quantitative MRA, is a multidisciplinary approach used for assessing the risks to human health from food-borne pathogens and can be used in the refinement of standards and regulations for food in international trade. The training consisted of a presentation on the process of qualitative and quantitative risk assessments, attending meetings on incidents and outbreaks occurring in the UK in that period and a series of meetings on a quantitative model developed within

FSA for transmission of norovirus in food products. After the initial training, the fellow was given an incident on a microbiological hazard (mould in fruit juice) on which to perform a rapid risk assessment and drafted a report for the risk management team to take action.

The fellow was also introduced to the various tools used by the MRA team for organising their day to day workload and research projects. These tools are necessary to plan and distribute the work within the team, especially when considering projects that are expected to last for some years in the future and require a lot of planning. Also, the weekly workload of each scientific officer of the team is planned and organised, so that the team manager is able to optimise the work of each researcher in the best way possible.

Additional training on probabilistic quantitative risk assessment modelling was provided, in which the fellow was trained in using the software @Risk and ComBase Predictive Models. This training allowed the fellow to gain a better knowledge on the quantitative modelling tools used to assess the risk of microbiological hazards in food.

2.2.2. Module 2

For the second module of the EU-FORA programme, the fellow was embedded within the CRA who deliver the national food safety risk assessment function for chemicals, allergens and radiological hazards. CRA also acts as the Secretariat to the COT. In this regard, CRA prepares and presents scientific papers and reports on toxicological relevant topics for the committee to discuss and review.

The second module started with training on the CRA activities, beginning with an introduction to the risk assessment process for chemicals (FAO/WHO 2009). Risk assessments usually comprise of four steps, namely hazard identification, hazard characterization, exposure assessment and risk characterization (FAO/WHO 2009). Hazard identification aims at collecting and summarising information on the hazard of interest, also in relation to the endpoints of concern for the specific risk assessment. In the hazard characterization section, the endpoints of concern are further evaluated in relation to the hazard; estimating the nature, severity and duration of adverse effects, also considering the subpopulations more at risk. The exposure assessment is focused on quantifying the exposure to the hazard of concern via a specific diet. The important information required is the concentration of the hazard and which food commodities are involved, in order to provide mean values of exposure to the hazard by different population groups, both for acute (short-term) and chronic (long-term) exposure. Finally, the risk characterisation assesses if there is a risk from the consumption of the food and, if there is, the magnitude and the population groups more at risk, together with an analysis of uncertainties. This process has been implemented by international health and food organisations, including EFSA, FAO and WHO. Risk assessments are an integrated part of the work in the CRA. For this reason, after having received the training, the fellow was presented with realistic examples of toxicological incidents for which he had to prepare rapid risk assessments with realistic deadlines and compare the results with the official ones produced for the risk management team by the CRA scientific officers. These risk assessments included topics such as supplements, pesticides, additives, contaminants and veterinary medicine residues.

Furthermore, the fellow received training by the EAT, focusing on the steps to follow for carrying out a quantitative exposure assessment, together with the tools commonly used at FSA, and the FSA dietary data on which the assessments are based on. The first training was on the use of Crème, a scientific software tool used within the FSA to obtain food safety exposure and intake assessment, using the national consumption survey. The Crème database includes additives, flavourings, contaminants, pesticides, novel food and ingredients. The data are used to model and predict the exposure and consumption of different populations, and the statistical analysis can be tailored by the user based on their needs. The fellow received both a theoretical and a practical training on Crème, from which he comprehended the different steps of an exposure assessment and how to analyse and present the results. The other training organised by EAT regarded the FSA dietary data, with a special focus on the National Diet and Nutrition Survey (NDNS). The NDNS is a continuous programme funded by Public Health England (PHE) and the FSA. It is carried out jointly by the MRC Epidemiology Unit through the Cambridge NIHR BRC Innovation Programme for the measurement of diet, physical activity and nutrition, and NatCen Social Research. NDNS is designed to assess the diet, nutrient intake and nutritional status of the general population aged 1.5 years and over living in private households in the UK. The fellow was also introduced to a new tool that can fully automate the collection of food consumption data and the coding of foods and portion sizes, called Intake 24. This tool uses a 24-h multiple pass recall method to obtain dietary data from participants, replacing the 4-day paper diary.

The training also provided a practical session, in which the fellow could see how the survey is carried out, together with the extraction and analysis of the data.

The EU-FORA programme included the development of a risk assessment on a chemical hazard to present at the COT, for which the fellow collaborated with scientific officers within the CRA and the EAT. The topic of the scientific report drafted was 'Potential risks from aggregated dietary exposure to mycotoxins' and focused on the UK population. Mycotoxins are toxic secondary metabolites produced by fungi and can cause adverse health effects in both humans and animals (Lee and Ryu, 2017, Palumbo et al., 2020, Smith et al., 2016, Shi et al., 2019, Battilani et al., 2020). Cereals are often the most severely affected crops. Acute and chronic exposure to mycotoxins can lead to several adverse effects in humans, including carcinogenic, teratogenic, hepatotoxic, nephrotoxic and cytotoxic effects. Natural co-occurrence of mycotoxins in food and feed is quite common and occurs for three main reasons: i) some fungi can produce more than one mycotoxin, ii) food commodities can be contaminated by several fungi and iii) animal and human diets usually consist of multiple commodities (Lee and Ryu, 2017, Alassane-Kpembi et al., 2017, Battilani et al., 2020). The fellow, together with another scientific officer within the CRA and with the help of the EAT, prepared a Discussion Paper for the COT on this subject. The paper contained details on the chemicals of interest, their relevance to human health, details on regulatory parameters previously assessed by COT or other international bodies, toxicological information, exposure assessment, risk characterisation and conclusions. The general format is for the contents of the paper to be discussed by the COT members during a meeting. Depending on the outcome of the discussions, further data and information may be requested. Ultimately, a statement will be prepared setting out the final views of the Committee. The paper on co-occurrence of mycotoxins prepared by the FSA scientific officers and the fellow was presented at the July COT meeting.

2.2.2. Module 3

In the third module, the fellow had the chance to work within the Social Science team at the FSA. In addition, the fellow attended the meetings of the AU, in order to gain insights on the different fields of research carried out by the experts in economics, statistics and social science working within the SERD.

The main task of this module was to perform a literature review on the mental models affecting the risk perception of lay people and the biases associated with expert judgement. The aim was to produce a manuscript gathering all the information on the subject, in order to provide recommendations to risk assessors for conducting unbiased risk assessments and to effectively communicate the results to the public.

This module allowed the fellow to gain insights into the work carried out within the AU, with a special focus on the importance of social science for conducting effective risk assessments. The fellow studied both the biases affecting the experts during their risk evaluations and the perception of the risk by lay people. A good knowledge of these two aspects by risk assessors would allow them to identify the biases affecting their judgements during the risk assessment process, in order to apply methods enabling the mitigation of those biases and thus to evaluate the risk of events in a more objective way. In addition, knowing the mental models affecting lay people's perception of the risk, risk assessors would be able to effectively communicate the results of their assessments, so that the public would grasp the true risk of an event.

2.2.3. Module 4

For the fourth module, the fellow had the opportunity to carry out a small project at the APHA, where the fellow was placed for 2 weeks. This project was part of the RaDAR (Risk and Disease burden of Antimicrobial Resistance) One Health European Joint Project (OHEJP) on AMR, which includes several European organisations. The deliverable for APHA is to develop a computational model that looks at the transmission of ESBL-producing *E. coli* on pig farms. The assignment for the fellow was to perform sensitivity analyses on the preliminary results of the model using the software R.

Sensitivity analysis (SA) can be used to evaluate how robust risk assessment and management strategies are, by assessing how variation of a model output can be attributed to variations in the different input factors (Tsao et al., 2019, Feyissa et al., 2012, Pianosi et al., 2016, Carlucci et al., 1999). This can be used for the ranking of the input factors, screening the input factors in order to identify which have a negligible influence on the output and for mapping the region of the input variability space that produces significant output values. There are several different methods of SA,

including regression analysis, difference in log-odds ratio (ΔLOR), scatter plots and analysis of variance (ANOVA) (Frey and Patil, 2002, Patil and Frey, 2004, Wu et al., 2013).

For this project, the fellow got the opportunity to read through and understand a large, complex, stochastic mathematical model showing farm-level transmission of pathogens of One Health importance. Then, he produced R scripts for the different methods of SA applied, namely scatter plots, regression analysis, ANOVA and heat maps. These scripts were then used for the evaluation and optimisation of the parameters of the model. This project allowed the fellow to receive an overview on the numerous methodologies for SA, to acquire a deeper knowledge on the analysis of models for the transmission of food-borne diseases and to use R.

Throughout the whole EU-FORA programme, the fellow had the opportunity to participate in various SACs meetings, including COM, COT, Science Council and ACMSF, and also a meeting of the UK Risk Network HAIRS. The fellow also attended the periodic seminars organised by FSA, 'Food for Thought' and 'Risky Bites', and the workshops and courses organised by the different teams of FSA. At the end of the programme, the fellow had the opportunity to share his personal experience; presenting the work carried out for the fellowship at a 'Risky Bites' seminar. Another important part of the module was his participation in Strategic Surveillance meetings; a series of sessions on a risk prioritisation surveillance tool developed for the FSA and other stakeholders to monitor data sources and learn about food risk signals (country – commodity – hazard) based on what has already occurred in places elsewhere.

3. Conclusions

The working programme 'Integration of tools and social science into food safety risk assessments' was an opportunity for the fellow to work in the different units of SERD at FSA and to gain experience on their day-to-day work in carrying out rapid risk assessments and longer term assessments. In particular, the first module of the programme was tailored for the fellow to learn how to carry out a systematic review and a rapid risk assessment for incidents and outbreaks. Furthermore, in the second module, he was introduced to chemical risk assessments; producing a series of risk assessments on hazards of toxicological interest and a scientific paper on the co-occurrence of mycotoxins that was presented at a COT meeting. The fellow also received training on several aspects of exposure assessment, both theoretical and practical, on the tools used for performing a quantitative exposure assessment (Crème) and on the national surveys in the UK (NDNS, TDS, Intake24), from which data are used for evaluating the exposure to the hazards by population type. The third module aimed at offering the fellow an understanding of the role of social science in the framework of food safety risk assessment. During this module, the fellow developed a literature review on the mental models affecting the risk perception of the public and the biases associated with expert judgement. The results were then used to provide recommendations to risk assessors, in order for them to examine the possible biases affecting their judgement during the process of a risk assessment and try to mitigate them, and also consider the risk perception of lay people in order to deliver an optimised communication of the risk. The fellow also attended the AU meetings to have an understanding of the activities carried out by the experts in economics, statistics and social science. For the fourth and final module, the fellow had the opportunity to take part in a small project at the APHA. The main task was to perform a sensitivity analysis for a model (developed by APHA researchers) assessing the spread of ESBL-producing *E. coli* within pig farms in UK. The fellow was trained on the theoretical methods for sensitivity analysis and then designed R scripts to evaluate the model parameters that have the largest and the least effect on the output. Moreover, the fellow had the opportunity to attend several meetings, including SACs, RAU and UK Risk Network, workshops and additional trainings that allowed him to improve his skills and expertise on the different steps of the risk assessment process. Overall, the programme was a useful overview for the fellow to gain insight on the different lines of work in the field of national food safety. At the end of the fellowship, he was able to perform a systematic review, to carry out risk assessments within realistic deadlines, to interact with people with different expertise to obtain the information needed and to understand the importance of social science in the field of risk assessment.

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Abbreviations

ΔLOR	difference in log-odds ratio
ACMSF	Advisory Committee on the Microbiological Safety of Food
ANOVA	analysis of variance
APHA	Animal and Plant Health Agency
AU	Analytics Unit
BRC	Biomedical Research Centre
COC	Committee on Carcinogenicity
COM	Committee on Mutagenicity
COT	Committee on Toxicity
CRA	Chemical Risk Assessment team
EAT	Exposure Assessment Team
EFIG	Epidemiology of Foodborne Infections Group
EU-FORA	European Union Food Risk Assessment

ESBL	Extended Spectrum Beta-Lactamases
FAO	Food and Agriculture Organization
FSA	Food Standards Agency
HAIRS	Human animal infections and risk surveillance group
MRA	Microbiological Risk Assessment
MRC	Medical Research Council
MRSA	methicillin-resistant *Staphylococcus aureus*
NatCen	National Centre for Social Research
NDNS	National Diet and Nutrition Survey
NIHR	National Institute of Health Research
OHEJP	One Health European Joint Project
PHE	Public Health England
QMRA	quantitative microbial risk assessment
RaDAR	Risk and Disease burden of Antimicrobial Resistance
RAU	Risk Assessment Unit
SA	sensitivity analysis
SAC	Scientific Advisory Committee
SACN	Scientific Advisory Committee on Nutrition
SERD	Science, Evidence and Research Directorate
VRG	Veterinary Risk Group
WHO	World Health Organization

Appendix A – Trainings and activities

	Title	Date
Training sessions	Introduction to incidents	20.11.2019
	Probabilistic Quantitative Risk Assessment course – Part 1	19.11.2019
	Probabilistic Allergy Risk Assessment course	5.12.2019
	ComBase training	21.01.2020
	Food Science training - Leatherhead Food Research (Epsom)	6.2.2020
	Introduction to Chemical risk Assessment	3.3.2020
	Introduction to food survey data collection and use by the FSA	31.3.2020
	Introduction to Exposure Assessment	6.4.2020
	Crème software training	24.4.2020
	Parma summer school	9-10.6.2020
	Qualitative risk assessment training course – session 1 - "An introduction to risk and risk analysis"	28.7.2020
Seminars and workshops	*Risky Bites* "More than one piece of career"	25.9.2019
	Risky Bites "Aqua Book"	15.10.2019
	Food for thought "Seeing is (not always) believing… multispectral imaging (MSI) for food screening"	21.11.2019
	Risky Bites "Norovirus: Reflections on lessons learnt"	9.12.2019
	Introduction to GSS guidance and the Aqua, Green and Magenta books workshop (London)	16.1.2020
	Risky Bites "EFSA Research Needs 2030"	12.2.2020
	One Health: Strengthening Animal & Plant Health Surveillance workshop – APHA (London)	26.2.2020
	Quantitative Risk Assessment workshop (London)	4.3.2020
	AMR Programme workshop	9.3.2020
	Potency estimation and PBPK workshop (Manchester)	11.3.2020
	Food for thought "Information-based regulation"	19.3.2020
	SOT FDA Food Safety Colloquium: Artificial Intelligence Applications in Food and Cosmetic Safety workshop	29.4.2020
	Food for thought "The Sociology of Nutrition and Food Choices"	13.5.2020
	Seminar on NDNS and Intake24 – MRC Cambridge/FSA	14.5.2020
	Risky Bites "Feed governance and Animal feed incidence"	21.5.2020
	Food for thought "The Role of Trust in People's Response to COVID-19 Communication"	1.6.2020
	Food for thought "Moments of Change and Food-Related Behaviours"	10.6.2020
	Food for thought "COVID-19: A food safety and fraud risk?"	15.6.2020
	Risky Bites "Risk: The Game"	26.6.2020
	Food for thought "Can digital technologies improve healthy diets?"	2.7.2020
	Seminar "The cost of food crime in UK"	10.7.2020
	Risky Bites "Understanding policy profession"	21.7.2020
	Food for thought "The impact of the FSA's Food Allergy and Intolerance Research Programme over the past 10 years"	4.8.2020

	Title	Date
Meetings	COM October meeting	10.10.2019
	ACMSF October meeting	17.10.2019
	AU November meeting	18.11.2019
	COT December meeting	3.12.2019
	SERD December meeting	10.12.2019
	Science Council meeting	17.12.2019
	Risk Assessment Meeting	14.1.2020
	AU January meeting	27.1.2020
	RAU March meeting	3.3.2020
	COT March meeting	10.3.2020
	CRA March meeting	27.3.2020
	SERD April meeting	27.4.2020
	COT May meeting	5.5.2020
	CRA May meeting	18.5.2020
	RAM May meeting	21.5.2020
	Levels and trends of Antimicrobial Resistance in Campylobacter *spp.* from chicken reared in the UK	27.2.2020
	AU June meeting	8.6.2020
	COT July meeting	7.7.2020
	SERD meeting	9.7.2020
Other activities	Chilled Food Production Site Visit	15.1.2020