FOODINTEGRITY

Ensuring the Integrity of the European food chain

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Deliverable: D1.2

Title: "Scientific opinions" on Food Integrity topics

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Dissemination level		
PU	Public	X
PP	Restricted to other participants	
RE	Restricted to a group specified by the consortium	
CO	Confidential, only members of the consortium	

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1. Description of Deliverable

In addition to feeding into WP2, WP3 and WP8, the expert panels formed in Task 1.3 were convened during FoodIntegrity project annual meetings and WP1 specific meetings to formulate "position papers" on a wide range of topics relating to food fraud and authenticity including all of those listed in Task 1.3. The "position papers" will be made available to Network members and regulators such as EFSA.

2. Achievement of the Deliverable

Task 1.4 of Work Package 1 was to prioritise, develop and publish (in open access format) "scientific opinions" on high priority FoodIntegrity topics.

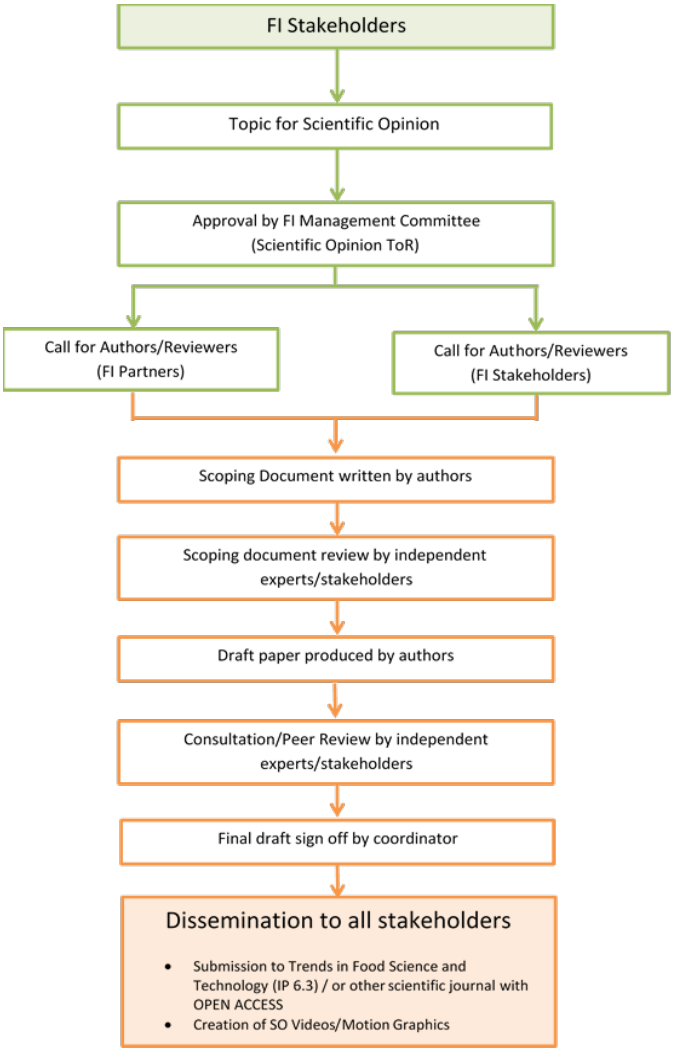
The Scientific Opinion is a document that describes the state-of-the-art and best practices as detailed by some of the FoodIntegrity experts in their respective fields. The paper is "commissioned" by stakeholders/end users, and reviewed by them to ensure it has met their objectives and finally formally peer reviewed before being published by a relevant scientific journal.

The topics for these opinion papers were selected by obtaining the key "questions" from various stakeholders in the FoodIntegrity Network (D1.1). Prioritisation of the topics occurred in two ways:

1. Stakeholders were given the opportunity to rank each topic by importance (1 - Low to 7 - High) – see ANNEX 1

2. Topic titles were then formulated and refined during the Work Package 1 meeting in Prague, Czech Republic on 04 April 2016 – see ANNEX 2

The WP1 Leader coodinated the process of writing the opinion papers and getting them reviewed by their selected stakeholders/end users (see ANNEX 3). At first, scopes for the papers were formulated by the authors, then they were sent to the selected stakeholders.



***2.1** Figure 1: Scientific Opinion Flow Chart.*

Each stakehoder was specifically picked by the WP1 Leader, from the FoodIntegrity Network for their knowledge of the topic as well as their potential use of this information. The main question asked of the FI stakeholder reviwewers was: are the authors answering your question about this topic? Reviewer responses were anonymised and sent to the authors.
Once the scope was agreed between the authors and the FI reviewers, the writing of the paper commenced. Various versions of the papers were exchanged via the Work Package 1 Lead, until the questions were answered in full.

Upon approval from the coordinator, all eight papers were submitted to various scientific journals for peer review and publishing. All of the papers have "open-access" paid for, by the work package to ensure the widest possible dissemination. At the time of writing of this deliverable, three scientific opinions have already been published, others are with the journals in press or in the review process. Figure 2, below, contains the FoodIntegrity Scientific Opinions Progress Tracker (up to December 2018).

SCIENTIFIC OPINIONS		0%	20%	40%	60%	80%	100%	
Topic No:	Topic Title:	Find Authors	Scope Written & Reviewed	1st Draft Writing & Review	Final Draft Writing & Review	Reviewers/users approved. Final paper submitted	SO Published	Info-graphic produced
1	Application of SIMRS for determining geographical origin in legal cases.	**Camin.et.al.** Trends in Food Science & Technology, Volume 61, March 2017, Pages 176–187					✓	✓
2	Role of analytical testing for food fraud risk mitigation – how much is enough?	**Francis Butler** – UCD					**Niels Lucas Luijckx**-TNO **Hans Marvin** - Rikilt **Vahid Mojtahed** – Fera	✓
3A	What are the scientific challenges in moving from targeted to non-targeted methods for food fraud testing and how can they be addressed? – Spectroscopy case study	**McGarth.et.al.** Trends in Food Science & Technology, Volume 76, April 2018, Pages 38-55					✓	✓
3B	The scientific challenges in moving from targeted to non-targeted mass spectrometric methods for food fraud analysis: a proposed validation workflow to bring about a harmonized approach.	**Cavanna.et.al.** Trends in Food Science & Technology, Volume 80, October 2018, Pages 223-241					✓	✓
4	Multivariate Statistics: considerations and confidences in food authenticity.	**K. Kemsley, M Defernez** – IFR, **F. Marini** - UNIROMA						✓
5	Database development, use and curation.	**James Donarski** – Fera					**Carsten Fauhl-Hassek** – BfR **Michael Sudnik**- Elementar **Federica Camin** – FEM	✓
6	Use of NMR applications to tackle future food fraud issues.	**Luisa Mannina** - UNIROMA					**James Donarski** - Fera **Freddy Thomas** - Eurofins	✓
7	The future of NGS analysis in testing food authenticity.	**Edward Haynes** - Fera					**Sarah Helyar** - QUB **Miguel Angel Pardo, Elisa Jimenez** - AZTI	✓

2.2 *Figure 2: Scientific Opinion Publication Progress Tracker (also showing the progress of the preparation of the associated animated infographic on the FI YouTube Channel (D1.3).*

In order to disseminate the information of these complex topics to a wider stakolder community, eight related animated videos have been produced by the work package. (See Deliverable 1.3 for further details).

Annex 5 contains the short summaries of the 8 Scientific Opinion papers that have come from WP1 of the FoodIntegrity Project.

ANNEX 1: FoodIntegrity Scientific Opinion Topic Suggestions and original Ranks from End Users/Stakeholders.

Ranks	Topic suggestion
7, 3, 5, 4, 7, 1, 5, nk	Method validation of non-targeted analysis – Discussion on potential validation parameters
6, 2, 4, 2, 2, 4, 2, nk	Current issues on authenticity along the supply chains of spices
1, 1, 1, 3, 6, 2, 1, 1	Current challenges in food authenticity/ food integrity
2, 5, 3, 7, 5, 5, 4, nk	Current methods for fish authentication
3, 5, 2, 6, 3, 6, 6, nk	Current issues on authenticity and traceability of cow and goat milk
4, 4, 6, 5, 1, 7, 3, nk	Current issues on honey authenticity
5, 5, 7, 1, 4, 3, 7, nk	Present and future of biomolecular techniques

ANNEX 2: List of final topics, their proposed authors and agreed by stakeholders

No	Topic	Authors	End User Reviewers
2	Application of testing/audit within risk mitigation strategies: how much is enough?	Francis Butler - UCD Niels Lucas Luijckx- TNO Hans Marvin - Rikilt Bouzembrak, Yamine - Rikilt Vahid Mojtahed - Fera	Industry (1 producer, 1 retailer), Regulator and Certification Body

3A	What are the scientific challenges in moving from targeted to non-targeted methods for food fraud testing and how can they be addressed? (**Spectroscopy)**	Simon Haughey, Chris Elliott (QUB) James Donarski (Fera) Carsten Fauhl Hassek (BfR) Saskia van Ruth - RIKILT	Regulator, Industry, Food control, Policy
3B	What are the scientific challenges in moving from targeted to non-targeted methods for food fraud testing and how can they be addressed? **(Spectrometry)**	Michele Suman – Barilla Saskia van Ruth - RIKILT	Regulator, Industry, Food control, Policy
4	Multivariate Statistics: considerations and confidences in food authenticity.	Federico Marini - UNIROMA Kate Kemsley - IFR	Contract Research organisation, Producer (primary production), Regulator, Certification body
5	Database development, use and curation.	James Donarski - Fera Carsten Fauhl Hassek – BfR Federica Camin – FMACH Michael Sudnik – Elementar Rob Posey - FF	Policy, Contract Research Organisation, Primary Producer, Certification Body
6	Use of NMR applications to tackle future food fraud issues.	Luisa Mannina (U Rome) James Donarski (Fera) Freddy Thomas – EUROFINS Anatoly Sobolev - CNR	Industry (1 Primary and 1 Multinational), Joint Research Centre, Control Body
7	The future of NGS (next generation sequencing) analysis in testing food authenticity.	Ed Haynes (Fera) Sarah Helyar – QUB Elisa Jiménez and Miguel Angel Pardo (AZTI);	Industry, Policy/Regulator, Control, Diagnostics?

ANNEX 3: Short Abstracts of the Scientific Opinion Papers

SO1: Stable isotope techniques for verifying the declared geographical origin of food in legal cases

Corresponding Author: Federica Camin (Department of Food Quality and Nutrition, Research and Innovation Centre, Fondazione Edmund Mach (FEM)) [Participant #15]

Background: Consumers are increasingly interested in the provenance of the foods and European laws require protection against the mislabeling of premium foods. Methods for testing authenticity

require robust analytical techniques that can be utilised by the various regulatory authorities. Of the many techniques, the most widely-used method is stable isotope ratio analysis.
Scope and approach: Focus is on the use of stable isotope ratios of H, C, N, O, S and Sr for verifying the geographical origin of food, cross-referencing it with examples of legal cases. State of the art including rules for building an authentic sample reference database (commonly called databank) and for interpreting the results obtained in actual cases is described. The overall objective is to provide stakeholders and competent authorities dealing with fraud, with the scientific context, state-of-the-art and a best-practice guide for its use.
Key findings and conclusions: Stable isotope ratios can differentiate foods on the basis of their geographical origin and, especially for light elements, can be measured reliably in routine work in different matrices and compared successfully between different laboratories. Examples of legal applications are grape products, orange juices, olive oil, cheese, butter, caviar. Sometimes stable isotopes are used to provide intelligence for further criminal investigation, where the cases are not brought directly to the court, but lead to further complementary verifications (e.g. paper traceability, forensic accounting). The system can satisfy the court when a robust databank of authentic samples exists, the methods used are officially recognized, validated and accredited, and the expert demonstrates that the conclusions are sufficiently robust and reliable to stand up to the required level of proof.

SO2: Role of analytical testing for food fraud risk mitigation – principles of cost-benefit determination for analytical fraud testing

Corresponding Author: Francis Butler (University College Dublin) [Participant #5]

Background: Food fraud is of high concern to the food industry. The practice is widespread, the nature of the fraud is varied and fraud can potentially happen at all stages in the food chain. A multitude of analytical technologies exist to detect fraud including chromatography, spectroscopy, DNA analysis, etc. However, in many cases testing is expensive and some forms of fraud, such as labelling changes, may not be detectable by analytical techniques. When analytical techniques are employed, the question immediately arises as to the extent and frequency of testing required.
Scope and Approach: In this commentary, several aspects relating to the role of analytical testing for food fraud risk mitigation are explored. In the first instance, available databases detailing fraud occurrences were systematically examined to determine how frequently analytical testing triggered fraud detection. In many cases, analytical testing was not the trigger to detect fraud. This work was complimented by a structured survey of industry stakeholders to determine their experience of how successful analytical detection has been to detect fraud. In addition, the paper considers a framework for deciding when to implement analytical testing programmes for fraud and a framework to consider the economic costs of fraud and the benefits of its early detection. Current regulatory issues relating to food fraud detection are explored as well as some of the main factors associated with statistical sampling for fraud detection. The occurrence of fraudulent product in the supply chain is typically not randomly distributed. Potentially this impacts on the success of the sampling scheme set up to detect fraud.
Key Findings and Conclusions: The decision to use analytical testing for food fraud risk mitigation is not straightforward. The decision is influenced by many factors including the

nature of the fraud, the likelihood of it occurring, the cost to the company arising from the fraud, the economic cost of testing, the probability of detection, availability of appropriate test techniques, health and safety considerations. This commentary provides guidance and insight for competent authorities to decide when to use analytical testing to mitigate food fraud risk.

SO3A: What are the scientific challenges in moving from targeted to non-targeted methods for food fraud testing and how can they be addressed? – Spectroscopy case study

Corresponding Author: Terry F. McGrath (Institute for Global Food Security, ASSET Technology Centre, School of Biological Sciences, Queen's University Belfast, Northern Ireland, United Kingdom) [Participant #6]

Background: The authenticity of foodstuffs and associated fraud has become an important area. It is estimated that global food fraud costs approximately $US49b annually. In relation to testing for this malpractice, analytical technologies exist to detect fraud but are usually expensive and lab based. However, recently there has been a move towards non-targeted methods as means for detecting food fraud but the question arises if these techniques will ever be accepted as routine.
Scope and approach: In this opinion paper, many aspects relating to the role of non-targeted spectroscopy based methods for food fraud detection are considered: (i) a review of the current non-targeted spectroscopic methods to include the general differences with targeted techniques; (ii) overview of in-house validation procedures including samples, data processing and chemometric techniques with a view to recommending a harmonized procedure; (iii) quality assessments including QC samples, ring trials and reference materials; (iv) use of “big data” including recording, validation, sharing and joint usage of databases.
Key findings and conclusions: In order to keep pace with those who perpetrate food fraud there is clearly a need for robust and reliable non-targeted methods that are available to many stakeholders. Key challenges faced by the research and routine testing communities include: a lack of guidelines and legislation governing both the development and validation of non-targeted methodologies, no common definition of terms, difficulty in obtaining authentic samples with full traceability for model building; the lack of a single chemometric modelling software that offers all the algorithms required by developers.

SO3B: The scientific challenges in moving from targeted to non-targeted mass spectrometric methods for food fraud analysis: A proposed validation workflow to bring about a harmonized approach

Corresponding Author: Michele Suman (Barilla Advanced Laboratory ResearchParma, Italy) [Participant #19]
Background: Detecting and measuring food fraud is a challenging analytical task since a very wide range of food ingredients and types may be adulterated by numerous potential adulterants, many of which are yet unknown. To date most of the methods applied for the control of food fraud are targeted methods, which are focused on the detection of one or a few classes of known compounds.
Scope and approach: There is an increasing availability of solutions and applications based on high resolution mass spectrometry (HRMS), allowing parallel non-targeted approaches,

novel compound identification and retrospective data analysis. For these types of methods samplehandling must be minimal to allow the inclusion of as many as possible chemical categories. However data-handling of such methods is much more demanding, together with the potential requirement to integrate multiplatform data as well as conducting data fusion. To allow the processing of massive amounts of information based on the separation techniques and mass spectrometry approaches employed, effective software tools capable of rapid data mining procedures must be employed and metabolomics based approaches does appear to be the correct way forward. To verify the relevance of modelling results, appropriate model validation is essential for non-targeted approaches, confirming the significance of the chemical markers identified.
Key findings and conclusions: The present paper is devoted to review and assess the current state of the art with regards non-targeted mass spectrometry in food fraud detection within many food matrices and to propose a harmonized workflow for all such applications.

SO4: Multivariate statistics: considerations and confidences in food authenticity problems

Corresponding Author: E K Kemsley (Quadram Institute Bioscience, Norwich, UK) [Participant #39]

Background: Modern analytical measurement technologies, such as infrared, NMR, mass spectrometry and chromatography, provide a wealth of information on the chemical composition of all kinds of samples. These instruments are invariably controlled by computers, and the data (spectrum, chromatogram) recorded in digital form. A measurement on a single sample typically comprises thousands of numbers. Usually, this is many more than the number of samples, meaning that the experiment overall is underdetermined. Furthermore, chemically different specimens often give rise to quite similar measurements, especially in some of the spectroscopy methods where there are large numbers of overlapped spectral bands. The task, then, is how to get the best out of these complex and unwieldy datasets. Fortunately, there is an assortment of computational methods that are especially suitable for dealing with this kind of data: these are the techniques of multivariate analysis.
Scope and approach: In this opinion paper, we present an overview of multivariate statistics for food authentication applications. We discuss the advantages of a multivariate strategy compared with univariate assessments and look at selected techniques that are now well established in analytical chemistry, such as the data compression methods of principal component analysis and partial least squares regression. We also consider predictive approaches suitable for authentication applications: discriminant and classification strategies, and class-modelling techniques.
Key findings and conclusions: Critical to the proper application of multivariate techniques is the concept of validation. We conclude by discussing some wider aspects of experimental design, such as the importance of representative sampling. Illustrations are drawn from real-world examples of food authenticity problems.

SO5: Sampling guidelines for building and curating food authenticity databases

Corresponding Author: James Donarski (Fera Science Ltd, York, UK) [Participant #1]

Background: Food fraud is a global issue and one that can often be detected through the use of analytical testing. Analysis of suspect foodstuffs and comparison of their results to those contained within a food authenticity database is a typical approach. This scientific opinion was commissioned as part of the FoodIntegrity EU project to provide guidance for the creation of these food authenticity databases.
Scope and Approach: This opinion paper provides what the authors believe are the most important considerations which must be addressed, when creating a food authenticity database. It covers three broad sections, relating to aspects that need to be considered before, during and after the analytical data has been collected. Specifically, the areas of database scope, analytical methodology, sampling, collection and storage of data, validation and curation are discussed.
Key Findings and Conclusions: The globalisation of foodstuffs brings new and novel commodities to consumers throughout the world. When foodstuffs are new to a specific population, it can be the case that consumers or even inspection laboratories cannot easily recognise when a fraud has taken place. The provision of available, reliable and robust food authenticity databases is a tool in preventing such fraud. This opinion was produced to facilitate the sharing of these databases.

SO6: Use of NMR applications to tackle future food fraud issues

Corresponding Author: Luisa Mannina (Institution Dipartimento di Chimica e Tecnologie del Farmaco, Sapienza Università di Roma) [Participant #38]

Background: NMR targeted and untargeted methodologies are widely recognized as important tools for food authentication and the detection of counterfeit products. Targeted approaches allow the identification of specific markers of identity/adulteration for a given foodstuff. In the untargeted approach, the chemical profile of the whole foodstuff is used to create a unique fingerprint as a reference for suspect samples. The untargeted analysis methodology typically follows the metabolomics approach.
Scope and Approach: In this manuscript we discuss how both targeted and untargeted NMR methodologies are applied in routine use for food fraud monitoring. The cost effective approaches for routine application are discussed using examples of Food Screener™ and benchtop low-field instruments.
Key Findings and Conclusions: Several examples of routine consolidated NMR targeted and untargeted applications are reported and the food matrices that are problematic for the NMR application are discussed. The future NMR implementation into routine practice will rely on the further exploration of FoodScreener™ like platforms for simultaneous targeted and untargeted applications and the continued development of applications for low-field benchtop instrumentation.

SO7: The future of NGS (next generation sequencing) analysis in testing food authenticity

Corresponding Author: Edward Haynes (Fera Science Ltd, York, UK) [Participant #1

Background: The authenticity of foodstuffs is an important issue for consumers, regulators, producers and processors, as fraudulent practices can negatively affect consumer confidence and safety, as well as the operating models of legitimate businesses.

Scope and Approach: This review provides an overview of the current use of Next Generation Sequencing (NGS) related to food authenticity, and suggests a number of future applications and directions for these technologies. Specific areas highlighted include the range of NGS platforms and sequence databases available, validation of NGS, and limitations and appropriate uses of these technologies.
Key Findings and Conclusions: Many NGS platforms are available, with different properties (such as sequence read length and output) suited to different analyses. Despite this wealth of options, more platforms are being brought out frequently, and advances such as reduced error rate will enable their expanded use for food authenticity. This rapid expansion in the use of DNA sequencing has led to an equally rapid enlargement in sequence databases, and the construction of contemporaneous, authenticated databases may be a useful innovation for the application of NGS to authenticity. Such applications will require robust quality control criteria and proficiency testing schemes, both of which are being developed. Despite several caveats, for example around effective extraction and amplification of DNA, NGS is a strong candidate to become a valuable aid or even the technology of choice to achieve regulatory compliance and reputation protection in a number of food fraud situations, particularly for highly complex food matrices.