FOODINTEGRITY
Ensuring the Integrity of the European food chain

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Seventh Framework Programme
KBBE.2013.2.4-01: Assuring quality and authenticity in the food chain

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<th>PP</th>
<th>RE</th>
<th>CO</th>
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<td>Public</td>
<td>Restricted to other participants</td>
<td>Restricted to a group specified by the consortium</td>
<td>Confidential, only members of the consortium</td>
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1. Introduction

1.1 Authenticity and Adulteration of food and beverages

Food Fraud occurs when products are deliberately diluted, mislabeled or misrepresented, tampered, substituted. Food adulteration started centuries ago, but recent scares such as melamine adulteration of milk powder and the horsemeat scandal have focused media, authorities & industry attention much more on this area. The deliberate adulteration of food and misrepresentation to deceive the consumer is illegal world-wide. Consumer protection is enshrined in general food law, compositional standards for agricultural commodities are protected, and general labelling regulations require detailed information about food and beverages to be provided. Additionally, specific labelling regulations provide information to consumers concerning organic foods, genetically modified organisms (GMOs) and foods of designated origins as well as ensuring traceability throughout the food chain.

There are a number of different terms used in this area such as adulteration, economic adulteration, authenticity, food fraud, deliberate mislabeling, substitution, misbranding and counterfeiting. Adulteration is the deliberate addition to food of a substance or substances with the aim of deceiving the consumer in terms of the quality of the food being traded. This addition could be of a single chemical such as Sudan I dye aimed at improving the color of spices to give the appearance of a higher quality. Alternatively, it could be simply blending (dilution) of a premium product such as virgin olive oil with a low-value vegetable oil at levels which cannot be readily detected by taste by the consumer. Although adulteration is a deliberate attempt to mislead in terms of the authenticity of a foodstuff, the same result can also be achieved by deliberate mislabeling without any adulteration taking place. Examples are deliberate mislabeling of wine or honey in terms of geographical or botanical origin. Again the deception is about misleading the consumer into believing a product is of a higher quality than it actually is and therefore misleading the consumer into paying a higher price.

Counterfeiting refers to the deliberate manufacture of a food or beverage mimicking a well-known product and using imitation packaging and labeling to pass-off as a recognized premium brand. This has most frequently occurred in the area of alcoholic beverages where illegally distilled alcohol is sold as a branded product such as vodka.

The term "traceability" is frequently used in the area of authenticity. It describes the process whereby all raw materials and all ingredients in a food or beverage can be "traced" back through the food chain, so there is documented evidence supporting their source and provenance.

In EU and USA law there is a statutory requirement on food suppliers to maintain a traceability system for all food products. Some of the most fraudulent foods are: olive oil, milk, honey, saffron, fruit juices, coffee, fish,...

56% of people say they are confident that what they are buying is exactly what is stated and 92% say it is important that local authorities test food to make sure it is labelled correctly. Food fraud is estimated to cost the global food industry US$30 to $40 billion every year. [John Spink, Michigan State University – 2016].

[ANNEX 1]
1.2 Overview of Regulation, Analysis and Future Trends

The external scenario after the horsemeat scandal, beside a number of growing examples of Food Frauds Prevention Models in EU and USA (such as FSA, USP, SSAFE, etc...) can be summarized with the following main points:


- **Food Safety Modernization Act USA** –final rules 2015: inclusion of food frauds with a Food Safety impact [https://www.fda.gov/food/guidanceregulation/fsma/]


- **BRCv.7**: requirements for food frauds prevention and control [https://www.brcgs.com/media/63848/brc_global_standard_for_food_safety_issue_7_faqs-1.pdf]

**LEGISLATION FRAMEWORK**

Regulation (EC) 178/2002 of 28 January 2002 establishes the general principles and requirements of food Legislation, which has as its objective the protection of consumer interests and the prevention of fraudulent or deceitful practices, the adulteration of foodstuffs and any practice that may lead to deception of the consumer. Furthermore, it also establishes the responsibility of operators of food companies for the foodstuffs to meet the requirements of the legislation.

Some “main” statements of the Premises of this Regulation n. 178/2002 of the European Parliament and of the Council (General Food Law) are:

“**The free movement of safe and wholesome food is an essential aspect of the internal market and contributes significantly to the health and well-being of citizens, and to their social and economic interest**”

“It is necessary to adopt measures aimed at guaranteeing that unsafe food is not placed on the market and at ensuring that systems exist to identify and respond to food safety problems in order to ensure the proper functioning of the internal market and to protect human health”.

Regulation (EC) 852/2004 of April 2004 establishes the general hygiene requirements to be met by food companies in all phases of the chain.

Regulation (EC) 882/2004 of April 2004 has as its objective guaranteeing legal practices in the marketing of fodder and foodstuffs and the protection of consumer interests, also regarding labelling and any other type of information for consumers. The tool used for this purpose takes the form of official inspections, which are any form of inspection carried out by the competent authority to verify compliance with the legislation. This regulation requires each member state to include in a single Plan all inspections carried out by the authorities involved in order to optimize the resources available.

More complete information on food authenticity legal framework can be also found in the regulations topic on the FARNHub tool (http://farnhub.authent.cra.wallonie.be/) developed in the EU-funded network project Authent-Net. The group of Authent-Net Partners experts have identified a range of existing resources, including national and international projects, reports, papers, publications, databases, standards and regulations. From it they have written 14 National status reports which detail commodity and country profiles in respect to food authenticity, integrity and traceability (http://www.authent-net.eu/AN_FARNH_click_map.html).
STANDARDS FRAMEWORK (BRC & IFS Examples)

The Global Standard for Food Safety (BRC), version 7, includes requirements referring to the adulteration of foodstuffs. Specifically, the declaration of intentions in basic requirement 3.5.1 on management of suppliers of raw materials and packaging and packing materials requires companies to have an effective System for approval and monitoring of suppliers that guarantees that any potential risk coming from raw materials that may affect the safety, authenticity, legality and quality of the finished product is understood and managed.

Afterwards, in the chapter dedicated to product inspection, in clause 5.4 about product authenticity, statements and chain of custody, it says literally "systems should be put in place to minimize the risk of buying fraudulent or contaminated raw materials."

The steps to be followed as stated are: access the information about past and present threats, assess and document raw materials according to their vulnerability and, if the raw materials run the risk of adulteration or substitution, have guarantee and/or testing processes to reduce the risk.

Furthermore, International Food Standard (IFS) Food also includes a requirement related to food fraud.

Clause 5.6.8 States, literally "based on a hazard analysis, evaluation of the associated risks and any external or internal information about the risks of the product that may have an impact on food safety and/or quality, the company will update its control plan and/or take appropriate measures to control the impact on the end product."

To conclude this paragraph please find here below 4 relevant schemes/images kindly provided by the following reference: “Looking forward to food fraud through the lens of the GFSI [FSSC 22000 ASIA Event – 11 November 2015 / Tokyo – Petra Wissenburg Food Safety External Affairs & Strategic Projects Director DANONE - GFSI Board Member]”:

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![Why is Food Fraud increasing?](image-url)

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Food Fraud in the Context of GFSI

Economically driven
Motivation is ‘GAIN’

Intentional adulteration

Ideologically driven
Motivation is ‘HARM’

Unintentional adulteration

Accidental Food borne illness

Integration of Food Fraud Mitigation in FSMS

Incorporation in GFSI Guidance Document Vs. 7 (2016)

Incorporation in Food Safety Management Schemes

Implementation and execution in companies’ FS Management System

Certification via third party audits

THE GLOBAL FOOD SAFETY INITIATIVE
1.3 Food Frauds Media Monitoring & Early Warning Systems

Work package 8 of Food Integrity project was in charge of creating and design software tools to provide an early warning system for food fraud. 3 tools were finally properly developed:

- Media mining tools for reporting of food fraud events.
- Fraud type prediction.
- Economic and trade trend analysis tools to detection potential for fraud

The Europe Media Monitor characteristics are:

- EMM applies text mining techniques to screen different types of media on the world wide web: websites, databases, blogs, ..etc.
- EMM is updated every 10 minutes, 24 hours per day, and gathers reports from news portals world-wide in 60 languages
- EMM contain 3 portals: NewsBrief, NewsExplorer and MedISys

MedISys-FF, as developed by RIKILT (Wageningen), is useful to collect publications in the media on food fraud. Food fraud reports are collected from all continents. MedISys-FF collects complementary information compared to RASFF, EMA and HorizonScan.
EMM Food Fraud Filter Design steps

1. Definition of food fraud key words
   - Scientific articles
   - Food Fraud articles
   - USP Database
   - EMA Database
   - RASFF

2. Validation of the key words by Food fraud experts

3. The design of the food fraud filter in EMM
   - EMM system

4. Evaluation and improvement of the filter
   - Analyse the articles
   - Relevance evaluation
   - Key words improvement

Figure 1: Design steps

Publication of MedISys-FF

Food Control
Volume 93, November 2018, Pages 283-296

Development of food fraud media monitoring system based on text mining
Y. Bouzembrak 1, A. B. Steen 2, R. Nisio 3, J. Liage 4, V. Mofahed 5, H. J. P. Marvin 6

https://doi.org/10.1016/j.foodcont.2018.06.003

Highlights
- A text mining food fraud tool MedISys-FF was developed.
- MedISys-FF collects food fraud articles with high relevance (>75%).
- MedISys-FF reports were compared to those published in RASFF.
Data visualisation in a dashboard using Kibana

Worldwide coverage of media reports on food fraud; 24/7, refreshed every hour

Early Warning System (EWS)
Early Warning System (EWS)

- Anomalous high volume, low price trade

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Early Warning System – Current system

- A dashboard of the latest “Early Warnings” for each commodity using traffic light system (RAG)
- Triggers visualization of red flags
- A temporal and spatial snapshots of warnings for each exporting country helping to identify global and systematic issues
- Summary statistics and major national suppliers (covering +190 countries) by commodity
- Trade network visualisation and automated identification of trading clusters
- Historical patterns, seasonality and long term trends of triggers (prices and quantities, etc.)
- Integrated with HorizonScan to explore past/recent types of food integrity issues
1.4 Food Frauds Prevention Model – general objectives / potential suggestions

1.4.1 Vulnerability assessment of raw material categories

Barilla, in its role of Work Package 10 coordinator, designed and validated the following simplified guidelines for setting an industrial food frauds prevention model.

In fact, food organizations are more and more required to assess and document their vulnerability to food fraud to identify potential risks and prioritize food fraud mitigation measures.

Supply Chain
• Map each step of the supply chain
• Identify points of vulnerability of the supply chain, evaluating opportunity, motivation and control for potential frauds

Potential Frauds
• Identify potential frauds
• Risk Assessment based on Severity and Likelihood
INDUSTRIAL FOOD FRAUD PREVENTION/ACTION MODEL:
*RMs CATEGORIES VULNERABILITY RANKING*

<table>
<thead>
<tr>
<th>RAW MATERIAL CATEGORY</th>
<th>STRATEGICITY</th>
<th>PURCHASING BUDGET</th>
<th>COMMUNICATION</th>
<th>PRICE VOLATILITY</th>
<th>PRICE</th>
<th>EXTERNAL RISK</th>
<th>GUT FEEL</th>
<th>VULNERABILITY SCORES</th>
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</thead>
<tbody>
<tr>
<td>Chain 1</td>
<td></td>
<td></td>
<td></td>
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<td>Chain 2</td>
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<tr>
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</tbody>
</table>
1.4.2 Definition of a mitigation plan
Food organisations are required to have a documented plan that specifies how it is reducing public health risks from identified food fraud vulnerabilities.
Mitigation plan

- Testing
- Audits focused on frauds
- Enhance security on the supply chain
- Build knowledge and awareness

A pilot for Olive oil supply chain

On going deepenings

**Knowledge**
- Visit on field of the supply chains
- Identify external experts of olive oil and likely forms of frauds

**Audits**
- Scouting of external auditors with expertise on frauds
- Test an audit focused on frauds

**Analytical methods**
- Conventional testing
- Not conventional testing
- Rapid methods
A final example of the entire process-protocol application can be practically summarized, for instance in the case of a potential organic vs conventional fraud issue, as here below:

<table>
<thead>
<tr>
<th>Supply Chain</th>
<th>Point of vulnerability</th>
<th>Type of fraud</th>
<th>Risk assessment</th>
<th>Analysis</th>
<th>Mitigation plan</th>
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</thead>
<tbody>
<tr>
<td>Organic Wheat</td>
<td>Storage</td>
<td>False organic farming declaration</td>
<td>Low risk</td>
<td>Pesticides residues LC-MS* IRMS**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- (Non-announced) Audit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Analytical check*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Documents (paper trailing; blockchain certifications, ...)</td>
</tr>
</tbody>
</table>

2. Food Fraud Prevention Guide directly connected with the HACCP system – a concrete example

FOOD FRAUD PREVENTION GUIDE FOR AGRIFOOD SECTOR. AN INTEGRITY ASSESSMENT TOOL FOR APPLIED STRATEGIES IN ORDER TO ASSURE FOOD AUTHENTICITY

This document was developed in the context of a public-private partnership, between the Agriculture Department (Government of Catalonia) and Premiumlab Company having also the support of the University of Barcelona, the Universitat Autonoma de Barcelona and the ACCA, the Catalan organization of food science.

GFSI schemes BRC and IFS include, in their current versions, terms related to food authenticity. Food industry needed a document to help them to control these circumstances. Therefore, commitment from all participants in the production chain is very important. On the one hand, from the suppliers who have to provide sufficient and appropriate information to increase their transparency; from the distributors who have to maintain the traceability of the products that they receive and manage, and from the Government, which has to protect legitimate businesses and reduce the number of illegal operations with dissuasive strategies.

Food fraud is a focal point for consumers, the Government and the industry due to the above-mentioned cases, but it is also extremely relevant for the industry because the main European certification standards (BRC e IFS) include requirements about product authenticity and assessment of the risk of substitution or fraud involving the raw materials.

This food fraud prevention System is aimed at all operators that already have their HACCP System and their prerequisite programme in place, follow good manufacturing and hygiene practices and need support in order to include the risk of suffering or causing food fraud.

The aim of this way of working is dual: on the one hand it provides a tool to the entire food business operators in order to prevent suffering a fraud by their own suppliers. On the other hand, it avoids making further costly mistakes in their own facilities. The analysis of the vulnerability enables the evaluation of risk considering different aspects of the raw material, the supply chain and the food processing. The system permits the evaluation of the severity of the occurrence. The main advantage of this system is that it fits perfectly with all type of companies, in any case at any time.

2.1 SUPPLY CHAIN MANAGEMENT: DATA SHARING & AND DIGITAL MASS BALANCING

Food Integrity Work Package 16 and Work Package 17, developed data-sharing/mass balancing digital systems/solutions in parallel to industry recommendations for the proper supply chain management:
Industry Recommendations Regarding Increased Food Integrity through Supply Chain Management and Digital Mass Balancing

Check X – Improving Supply Chain Integrity through Data Sharing

1. Food fraud results in the sale of a less valuable product disguised as a more valuable product. The volume of the more valuable product is artificially increased along the food supply chain.

There are many different techniques used to commit food fraud. Yet, because food fraud is economically motivated, all techniques result in the artificial increase of the volumes of the more valuable product. For example, a lower quality product is sold as a higher quality product, or a non-certified product is sold as a certified product. It is therefore helpful to shift the perspective from the food product and its properties alone, to that of the entire supply chain as facilitating the flow of product volumes from the field where it originated to the consumer.

2. A mass balance approach detects food fraud by checking whether traded volumes are plausible.

Mass balancing describes a calculation that compares the product volumes that are “input volumes” and the product volumes that are “output volumes”, while also considering conversion factors (output = input * conversion factor). Conversion means the processing of a commodity, e.g. olives to olive oil, cocoa beans to raw cocoa products. By collecting data on commodity production, meaning acreage data and expected or real yields, it is possible to check whether the traded volume of a specific commodity is plausible by comparing it to expected production volumes and check whether food fraud has likely occurred along the supply chain.

3. Companies and/or sectors can use mass balancing as a mechanism for supply chain transparency and for food fraud prevention and detection.

By creating a defined supply chain and ensuring that every supply chain actor is known through a registration, certification, or quality control system, companies and/or sectors can apply mass balancing to ensure that artificial increases of the volume of a product with specific attributes such as a certification or product quality do not occur. The use of digital tools for registration or certification of supply chain actors as well as mass balancing within a given timeframe (a day, year, or harvest cycle for example) is a key success factor.
4. Check X is a cloud-based tool that combines mass balancing with certification data and is readily available to companies and/or sectors.

Check X is a cloud-based platform that combines real-time certification with real-time transaction data across the supply chain. It is a solution that can be applied in all commodity-based supply chains. Check X manages data confidentiality through client set-up and a system of rights and roles. Check X uses a traffic light system (red, yellow, and green lights), which was highlighted as intuitive to immediately understand. Single company supply chain solutions as well as system-wide solutions (national, product based, Geographic origin, etc.) based on registration or certification of all system participants are feasible. Check X is a tested and effective tool for food fraud prevention in the food industry in Europe and beyond.

5. A successful Check X application allows participants to prevent food fraud and is also financially viable for companies.

A survey among users of a Check X implementation in the Italian organic grain sector, called the FederBio Integrity Platform, showed that the integrity system was perceived to be successful in preventing and/or detecting fraud. It also showed that there is a significant potential for cost and time savings due to this type of sector-wide integrity management system, once most supply chain actors adopt the integrity management system. It is important to note that the time investment required for mass balancing systems is lower than what is required for other approaches such as chain batch traceability systems, as mass balancing requires input and output checks rather than integration of suppliers’ batch numbering into in-house systems and communication to the next level, at each step of the supply chain.

6. Check X can be combined with other innovative digital tools and technologies.

The integration and/or combination of other innovative technologies and data such as from satellites, sensor data from internet of things or remote-sensing technology with Check X can be used to collect evidence and supply chain related data. Also, distributed ledger technology for the encryption of selected data might be of interest. This can further increase supply chain transparency and integrity.
A lot of (types of) data...

Information may be a puzzle

- Awareness and alertness for early signals is crucial
- Also in food fraud identification and prevention
- However....
  - Interpreting them is a major challenge
  - Making the right scenario, without over-reacting (making a justified risk management decision)

Even a jigsaw puzzle with missing pieces can reveal an overall picture.
Generalized relation between data and timing

Generalized timeline: indicators and where to find them

<table>
<thead>
<tr>
<th>Food technology opportunities</th>
<th>Price data of commodities and cheaper alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability, production, storage and trade data of food quality chemical residues</td>
<td>Availability, production, storage, transport and trade data of commodities and cheaper alternatives (volumes)</td>
</tr>
<tr>
<td>Regulatory Information</td>
<td>Border Inspections</td>
</tr>
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</table>

Types of data:

<table>
<thead>
<tr>
<th>Broad category of data</th>
<th>Relevant for which case</th>
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</thead>
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<tr>
<td>Socioeconomic information</td>
<td>Melamine (2008); Horsemeat (2012); Organic food (2011)</td>
</tr>
<tr>
<td>Price data of commodities and cheaper alternatives</td>
<td>Horsemeat (2012); Organic food (2011)</td>
</tr>
<tr>
<td>Flow of information and money within supply chain/company</td>
<td>Melamine (2008); Horsemeat (2012); Organic food (2011); Fipronil (2017)</td>
</tr>
<tr>
<td>Availability, production, storage and trade of chemicals that mimic food quality aspects</td>
<td>Melamine (2008)</td>
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<tr>
<td>Food technology opportunities</td>
<td>Melamine (2008)</td>
</tr>
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<td>Historical fraud cases</td>
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<td>Regulations</td>
<td>Horsemeat (2012); Organic food (2011)</td>
</tr>
<tr>
<td>Border inspections</td>
<td>Horsemeat (2012)</td>
</tr>
<tr>
<td>Laboratory results</td>
<td>Melamine (2008); Horsemeat (2012)</td>
</tr>
<tr>
<td>Toxicology</td>
<td>Melamine (2008)</td>
</tr>
<tr>
<td>Animal health</td>
<td>Melamine (2008)</td>
</tr>
<tr>
<td>Human health</td>
<td>Melamine (2008)</td>
</tr>
</tbody>
</table>
Solutions....
Conceptual model

Technical solution

Other information:
Science; WWW; Authorities; Branches; Associations; Public; ....

DATA Integration, analysis and management
Tools and experts

DATA WAREHOUSE & EXCHANGE NODES

@ trusted third party

Food production network
Framework

Signal dissemination

Prediction

Early warning

Real time

Early, Process, Outcome Indicators

Data Analysis

Predictive Model

Text Analysis

Data Governance

Data sources

- Price data of commodities and cheaper alternatives
- Flow of information and money within supply chain or company
- Availability, production, storage and trade data of chemicals that mimic food quality aspects
- Laboratory results

Practical modus operandi

IN-chain data

Using “mass” balance

Input-output

“paper” trail and work

Data and text mining

At each interface: compare products, volumes, quantities, formulation & test results

Supplier

Processor

Distributor

Retailer

producer

producer

producer

producer

product

product

product

product

volume

volume

volume

volume

quantity

quantity

quantity

quantity

formulation

formulation

formulation

formulation

country

country

country

country

sector

sector

sector

sector

data

data

data

data

test results

test results

test results

test results

Transaction documents

Transaction documents

Transaction documents

Transaction documents

Block chain... ??
2.2 FLOW CHART & VULNERABILITY ASSESSMENT
Based on the HACCP flow chart the hazard points for entry of possible frauds should be identified. Everyone should adapt it to the production environment, based on the HACCP System flow chart, taking account of each manufacturing unit or machine individually. To carry out the assessment of the risk of fraud, there should be measurement, on the one hand, of the vulnerability of it happening, i.e. the likelihood, and, on the other hand, the severity of fraud occurring. Every company should adapt them to their own practices. The vulnerability analysis is carried out in a different way depending on whether the possible origin of the fraud stems from the raw materials or the processing.

Implementing Process Analytical Technology for food integrity was object of a deep evaluation through the activity of Work Package 20:
- The analytical tools for measurement of integrity are moving the food analysis closer to the process according to the PAT (Process Analytical Technology) paradigm: the measurement of critical process parameters, affecting critical quality attributes
- This will lead to identification of the critical steps for integration of the analytical methods in the food supply chain, by assessing the best tools to analyze and assess the quality and/or the authenticity of a specific product, in the context of a particular company/a given supply chain
- The identification of vulnerable areas within each supply chain is currently addressed without specific approaches. It must consider intrinsic vulnerability as well as extrinsic vulnerability, derived from external factors and inputs

WP20 works then closely with Barilla also for elucidating 2 case studies on complex foods such as Meat sauce and Filled pasta.

![Flow Chart Image](image-url)
Production Chains Analysis

Process Flow Diagrams (PFD) of preparation of the two complex foods analyzed: ready-made sauce (Bolognese sauce) and stuffed pasta (Tortellini filled with meat) were constructed, in order to provide a clear and simple description of the steps involved in the production processes. The following PFDs resulted from the application of network analysis to the two food supply chains identifying the connections among the various steps and depicting movements of materials, inputs, and outputs. The key analytical steps have been positioned on the maps. The principles of process analytical technology (PAT) and fuzzy logic analysis of flow diagrams along with the obtained experimental results have been implemented to identify the critical steps that have the most relevant effect on the integrity of the final products.
MEAT SAUCES

1. Verify the presence of meat according to recipes
2. Examine the presence of other kinds of meat
3. Assess the presence of a specific breed if required
4. Quantify the proportion of bovine and porcine meat
5. Verify the presence of tomato, eventually a specific cultivar
6. Identify the presence of other vegetables, possibly allergenic
7. Identify the spices to avoid substitution with cheap equivalents

FILLED PASTA PREPARATION

1. Verify the presence of the right type of meat, eventually breeds
2. Verify the presence of cheese (Parmigiano Reggiano) and eggs
3. Identify the presence of sunflower oil and exclude other sources of cheap oil
4. Verify the spices according to the recipe
2.3 RAW MATERIALS FRAUD PREVENTION SYSTEM IN THE FOOD INDUSTRY

This section analyses the level of vulnerability to which the company is exposed in relation to selection of suppliers and control of the quality of the raw materials. For this purpose, the analysis involves the vulnerability derived from the history of fraud for each raw material, the associated economic and geopolitical considerations, the supply chain and the relationship with the supplier. Furthermore, the analysis looks at the type of quality control being carried out on each raw material.

2.4 REVIEW OF THE HISTORY OF FRAUD

Based on the list of raw materials and end products, a compilation should be made of the bibliographical information concerning possible associated fraud. Evaluation of the incidents that have occurred previously and observation of the market situation can help to understand the vulnerabilities that have to be faced and will put production into a global context. There are two basic sources of information: the Rapid Alert System for Food and Feed, RASFF, which is based on the rapid exchange of information about risks for health in relation to food and feed. On its website, every food alert that has taken place throughout Europe can be found. At national level, management of the food alert network takes place through the Coordinated System of Rapid Information Exchange (SCIRI), which can also be consulted Online. Elsewhere, a good source of information is the USP Food Fraud database, which contains a collection of scientific articles/press reports. A possible classification can be:

*Low vulnerability (value=1)*
There are no bibliographical references in any similar or equivalent ingredient and there is no substantial evidence.

*Medium vulnerability (value=3)*
Moderate-high number of reports. There are no alerts from the authorities.

*High vulnerability (value=5)*
High number of reports. There are alerts from the authorities.
**WORK TEAM FLOW CHART**

- RAW MATERIALS
- PROCESSING
- DISTRIBUTION

**STORAGE OF RAW MATERIALS**
- DELIVERY OF PRODUCTS TO PRODUCTION
- WEIGHTING OPERATIONS
- MIXING OPERATIONS
- OTHER PROCESSING OPERATIONS
- PACKAGING
- LABELLING

**RISK ASSESSMENT**

<table>
<thead>
<tr>
<th>VULNERABILITY</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>History of fraud</td>
<td>1</td>
</tr>
<tr>
<td>Economic and geopolitical considerations</td>
<td>3</td>
</tr>
<tr>
<td>Supply chain</td>
<td>1</td>
</tr>
<tr>
<td>Relationship with supplier and history</td>
<td>3</td>
</tr>
<tr>
<td>Raw material quality control</td>
<td>1</td>
</tr>
<tr>
<td>Storage and traceability</td>
<td>1</td>
</tr>
<tr>
<td>Calibration</td>
<td>1</td>
</tr>
<tr>
<td>Hygiene and cleaning</td>
<td>1</td>
</tr>
<tr>
<td>Human Resources</td>
<td>1</td>
</tr>
<tr>
<td>Information given to consumers</td>
<td>1</td>
</tr>
<tr>
<td>Sub-contracting*</td>
<td>0</td>
</tr>
</tbody>
</table>

| Table 1. Calculation of vulnerability level. *vulnerability is equal to 0 if no process is sub-contracted. |

**RISK - Vulnerability-Severity Ratio**

<table>
<thead>
<tr>
<th>SEVERITY - Impact of occurrence</th>
<th>HIGH - 5 - Critical hazard</th>
<th>MEDIUM - 3 - Major hazard</th>
<th>LOW - 1 - Minor hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 2. Relationship between vulnerability and severity.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

"RED": high risk (8-10)  
"YELLOW": medium risk (3-6)  
"GREEN": low risk (1-2)
2.5 GEOPOLITICAL AND ECONOMIC CONSIDERATIONS
The origin of the ingredient, the regions it passes through and where it is handled should be taken into account. There is more likelihood of fraud in developing countries due to strong political and social pressure, in regions with a less advanced regulatory framework, where there is more political instability or prevalence of corruption. In addition, the more different regions it passes through, the greater the risk.
Furthermore, temporary circumstances that raise suspicion that something unusual is happening should also be taken into consideration. Some examples are price below the market rate, fluctuating prices or those that increase disproportionately in the same sector or prices that are unusually steady in respect of competitors. Finally, and most of all, for ingredients that are solely produced in a specific region or that are seasonal, if the prices remain steady after a natural catastrophe or a poor harvest, there may be suspicion of fraud.

Low vulnerability (value=1)
One or more components with geographical origins giving little cause for concern.

Medium vulnerability (value=3)
One or more components comes from or has been transported through regions with certain causes for concern arising from their politics. Anomalies are detected frequently but are unrelated to one another. One or more components comes from or has been transported through regions with a lot of cause for concern. Anomalies related to one another are frequently detected.

Providing recommendations to industry for improved communication of European products to China – An example of EU-Asia import/export interactions (developed by Work Package 7)

Why is it important?
• Chinese consumers are becoming increasingly concerned about the safety of locally produced food products due to a number of recent, high profile food scares.
• China is an important market for European products, which are considered as safe.
• The demand for European products make them a target for dishonest traders.
• Food fraud and food safety are interlinked in the mind of the Chinese consumer.

Recommendations - Product
• European products are perceived to be safer and more trustworthy than products locally produced or positioned as locally produced in China. The country of origin of the product should therefore be clearly displayed.
• Accreditation through third party certification bodies, such as geographic indications certification (PDO) and organic certification, were viewed favourably so products should be clearly labelled as such.
• Industry certification, such as geographical indications certification for Scotch Whisky, can help to capitalise on the country of origin of products.

Recommendations - Packaging
• Authenticity cues on packaging are important. Consumers have more trust in measures that are difficult to replicate, such as tamperproof seals.
• Preference for the type of authenticity cue(s) is product specific so market research should include this as an important part of product testing.
• Chinese consumers are prepared to pay a premium for trustworthy authenticity cues so authenticity and safety guarantees usually add net value to products.
• Although highlighting these measures may also help counterfeiters, regularly updating authenticity processes was thought to help industry stay one step ahead of the fraudsters, and maintain consumer trust with their efforts.
Communications

- Chinese consumers require increased information on product categories e.g. olive oil, to improve consumer confidence and contribute to brand protection.
- Consumer reassurance could be provided by professional, independent 3rd parties who could supply trusted food safety information to the public.
- Communications should serve to reassure consumers about the safety of products, in addition to the authenticity.
- Targeted communication of authenticity assurance measures would raise consumer understanding and enable them to select products that use such measures.

2.6 SUPPLY CHAIN

It is directly connected to the traceability of the raw material. Vulnerability will be related to the level of control by the various interested parties involved in fraud prevention. In addition, the supply chain influences the likelihood of incorrect labelling of origin or false source of raw materials, either because it is a product unfit for consumption or by-product diverted for human consumption, a frozen product sold as fresh, or it is illegally slaughtered meat, among other examples. Furthermore, the longer the journey from origin and the greater the number of intermediaries involved, the more opportunities there are to commit fraud.

Low vulnerability (value=1)
Integration, all production comes from the company. It is considered that they act ethically and with the same quality policy.

Medium vulnerability (value=3)
All raw materials come from a single, trusted supplier (primary supplier), which may or may not manufacture its product, or which buys raw or processed ingredients from a third party (secondary supplier).

High vulnerability (value=5)
Set of ingredients, each manufactured by a different supplier or the ingredient is processed by another producer before final processing by the supplier, for example, a distributor. Any other scenario not mentioned.

2.7 RELATIONSHIP WITH SUPPLIER AND HISTORY

The supplier is the final intermediary in the supply chain and over which a more direct influence may be held. A close relationship with the supplier gives more knowledge about the environment and more trust.

The type of problems that have occurred and the time taken to solve them have to be taken into account. It is important to assess the frequency with which quality and food safety issues arise and how quickly and completely they are resolved.

It has to be taken into account whether the supplier has a certificate recognized by the GFSI since if this is the case, it will already receive annual audits by the certification companies, and will therefore be subject to greater control.

Low vulnerability (value=1)
Known and trusted supplier, supplies a single raw material. No issues are directly known about or if there have been any they have been resolved quickly and appropriately. The supplier holds valid certification from IFS, BRC or FSSC 22000. If a new ingredient is provided, it is mandatory to obtain approval for this ingredient.

Medium vulnerability (value=3)
Established supplier with a short period of previous business or supplier respected in the market, with which a business relationship has not been previously established. Has had an issue that was not resolved appropriately.

*High vulnerability (value=5)*

Non-established supplier, which has been involved in ongoing issues, which it has not corrected appropriately or quickly enough. There is evidence that appropriate checks are not made and that the level of cause for concern is unacceptable.

### 2.8 RAW MATERIAL QUALITY CONTROL

The quality of the raw material received is essential for the quality of the product to be produced. This quality mainly depends on the conditions of delivery and receipt and on adulteration of raw materials.

*Low vulnerability (value=1)*

The raw material is approved and analyses are made before the start of supply and periodically during supply. Full temperature monitoring is performed during transport by means of a temperature recorder and effective weight control is carried out on all batches prior to acceptance on calibrated scales and using validated procedures.

*Medium vulnerability (value=3)*

The raw material is approved but no control testing is performed. A check of the conditions of transport is carried out through a checklist, the effective weight of certain batches only is checked but without any validated procedures or calibrated scales.

*High vulnerability (value=5)*

The raw material is not approved nor is it analysed before or during the supply. No checks are made before acceptance of the batches, nor are there any conditions of delivery or effective weighing.

### 2.9 STORAGE AND TRACEABILITY

It is necessary for the raw materials and intermediate products to be arranged in their proper place and labelled individually and unmistakably. In addition, they should be able to be located quickly and monitoring should take place throughout the entire production process. Raw materials and intermediate products that are incorrectly labelled or are not identified may confuse the operator when it comes to adding them to the production process, leading to errors in the formulation. Proper Storage and a correct traceability System make it possible, as well as better control of stock, to avoid confusion between one product and another, which would compromise the authenticity of the finished product.
### PREVENTION AND/OR MITIGATION MEASURES

<table>
<thead>
<tr>
<th>STAGE</th>
<th>VULNERABILITY</th>
<th>PREVENTIVE MEASURES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>History of fraud</td>
<td>No preventive measures exist. Change raw material or supplier, if possible.</td>
</tr>
<tr>
<td></td>
<td>Geopolitical and economic considerations</td>
<td>No preventive measures exist. Change raw material or supplier, if possible.</td>
</tr>
<tr>
<td></td>
<td>Supply chain</td>
<td>Audit of supplier’s supplier.</td>
</tr>
<tr>
<td></td>
<td>Relationship with supplier and history</td>
<td>Questionnaire. Audit. Certification requirement.</td>
</tr>
<tr>
<td></td>
<td>Raw material quality control</td>
<td>Sampling plan. Temperature monitoring. Checking of effective weight.</td>
</tr>
<tr>
<td></td>
<td>Storage and traceability</td>
<td>Electronic identification.</td>
</tr>
<tr>
<td></td>
<td>Calibration</td>
<td>Validated calibration plan and procedures.</td>
</tr>
<tr>
<td></td>
<td>Hygiene and cleaning</td>
<td>Validated cleaning plan and procedures.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Training plan that includes traceability. Good Manufacturing Practices and fraud prevention.</td>
</tr>
<tr>
<td>PROCESSING</td>
<td>Human Resources</td>
<td>High motivation of workers, sense of belonging.</td>
</tr>
<tr>
<td></td>
<td>Information given to consumers</td>
<td>Written review. Checking of flow chart. Checking of weight according to Royal Decree 1801/2008 and its amendments.</td>
</tr>
<tr>
<td></td>
<td>Sub-contracting</td>
<td>Audit of sub-contractor.</td>
</tr>
</tbody>
</table>

### PRACTICAL EXAMPLE

**Product:** BEEF—dried powder from fresh or frozen meat

<table>
<thead>
<tr>
<th>STAGE</th>
<th>HAZARD</th>
<th>VULNERABILITY</th>
<th>RISK</th>
<th>Detection</th>
<th>PREVENTIVE MEASURES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>History of fraud</td>
<td>3</td>
<td>3</td>
<td>high</td>
<td>Surveillance for alerts.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Assessment of supplier.</td>
</tr>
<tr>
<td></td>
<td>Geopolitical and economic considerations</td>
<td>1</td>
<td>3</td>
<td>high*</td>
<td>Surveillance of changes to environment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Assessment of supplier’s suppliers required.</td>
</tr>
<tr>
<td></td>
<td>Supply chain</td>
<td>5</td>
<td>3</td>
<td>medium</td>
<td>Questionnaire. Audit. Certification requirement.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Airtight packaging. sealed containers.</td>
</tr>
<tr>
<td></td>
<td>Relationship with supplier and history</td>
<td>1</td>
<td>3</td>
<td>high</td>
<td>Questionnaire. Audit. Certification requirement.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Assessment of supplier’s suppliers required.</td>
</tr>
<tr>
<td></td>
<td>Raw material quality control</td>
<td>3</td>
<td>3</td>
<td>high*</td>
<td>Performance of DNA analyses.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Electronic identification.</td>
</tr>
<tr>
<td></td>
<td>Storage and traceability</td>
<td>1</td>
<td>3</td>
<td>high</td>
<td>Validated calibration plan and procedures.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Validated cleaning and hygiene plan and procedures.</td>
</tr>
<tr>
<td></td>
<td>Calibration</td>
<td>1</td>
<td>3</td>
<td>high</td>
<td>Training plan that includes traceability and Good Manufacturing Practices.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Training concerning food fraud.</td>
</tr>
<tr>
<td></td>
<td>Hygiene and cleaning</td>
<td>1</td>
<td>3</td>
<td>high</td>
<td>Regular written reviews.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Checking of flow chart.</td>
</tr>
<tr>
<td></td>
<td>Human Resources</td>
<td>3</td>
<td>3</td>
<td>high</td>
<td>Audit of sub-contractor.</td>
</tr>
<tr>
<td></td>
<td>Information given to consumers</td>
<td>1</td>
<td>3</td>
<td>high</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sub-contracting</td>
<td>1</td>
<td>3</td>
<td>high</td>
<td></td>
</tr>
</tbody>
</table>

*Detection is considered to be high if DNA analyses are performed. If they are not performed, detection is low.*
3. Food Fraud Industrial Prevention/Action Model

Guidelines for developing a cost-effective and practical Industrial Food Fraud Prevention/Action Model imply the need of a constant comparison with science-based indicators, following these steps:

**Step 1. “Practical” Industrial Vulnerability assessment**
The model starts off with an evaluation of the following factors

- Strategic side: purchase volume and communication (brand relevance for the company)
- Price: price/ton
- Price volatility: %/year
- External risk: historical evidence
- ‘Gut feel’: rumors, media attention, price difference
Limits/potential improvements of this “practical” approach:
- The value of these factors are multiplied.
- The factors considered are a mixture of economic impact and fraud vulnerability factors.
- The strategy aspect relates to impact and probably the price/ton as well.
- This is in fact a sort of scoping, the other factors relate to vulnerability: they consist of two economic factors, and two that relate most to technical opportunity and previous or recent occurrences (external risk and ‘gut feel’).
- Factors that are not considered here are opportunities in time and place (easy access, transparency in the chain) and detectability (this may also diminish opportunity in general).
- Regarding motivations, supply and demand is somewhat reflected in price volatility, but may need some additional attention, as well as the special attributes of certain products (e.g. organic).
- Although the economic drivers are included, the aspect of culture and behavior is not directly present here: this includes aspects such as business strategy, ethical business culture, corruption level of a particular country, previous criminal offences, financial strains imposed on the suppliers. One should/may also consider these aspects for both the own organization as well as for external parties.

An example of scheme that clarify how to proceed with a vulnerability assessment can be easily downloaded by the SSAFE website. Non-profit organization SSAFE is an industry-led solution that supports the Consumer Goods Forum’s Global Food Safety Initiative (GFSI) requirements. SSAFE developed the assessment with PwC, Wageningen University, VU University Amsterdam and in consultation with food industry leaders around the world to help put companies themselves in a stronger position to fight fraud [www.ssafe-food.org to download the assessment in Excel or online at www.pwc.com/foodfraud]. SSAFE Food fraud vulnerability assessment It is a science-based tool, based on the study of criminal behavior and decision making. Structured into two parts, the first part gets to the elements affecting criminal behavior, while the second part relates to company and its external relationships and environment (such as suppliers).
Food Fraud Vulnerability Assessment Tool

**Practical Tool**

Help companies undertake a vulnerability assessment

Help companies prepare a plan to mitigate the identified vulnerabilities

---

**Food Fraud Vulnerability Concept**

- Valuable ingredients/products
- Supply/demand and pricing ingredients/products
- Economic conditions
- Economic health of supplier
- Level of competition
- Financial strains
- Business strategy
- Ethical business culture
- Victimization
- Personality traits
- Criminal offences

- Complexity of adulteration products
- Availability technology & knowledge to adulterate
- Detectability fraud
- Interference/access processing lines
- Transparency chain network
- Historical evidence

- Fraud monitoring system and verification of the system
- Information system (mass balance, track and trace)
- Ethical code of conduct
- Integrity screening of employees
- Whistle blowing
- Contractual requirements suppliers
- Social control chain network
- Legal framework and enforcement
Step 2. Ranking of product groups
Based on Step 1 the product groups are ranked. Although it is attractive from a food perspective to think in product groups, one has to consider that in every group opportunity and economic drivers will be present, the human aspect will determine whether people are likely to cross the line.

Step 3. Mitigation strategy
Step 3 concerns (1) The mapping of the supply chain and determination of vulnerable points, (2) Identification of potential frauds, and (3) Definition of a mitigation plan.
In Part 1 it is stated that one looks at opportunities, motivations and controls. In the control plan (3) analyses and audits are considered as well as supply chain controls. Do not forget about the verification of the fraud monitoring tasks, the administrative controls, as well as an evaluation of the soft controls both in the own organization and suppliers’ organizations (whistle blowing, ethical code of conduct, integrity screening) and existence of fraud prevention laws and their reinforcement.
Selection/evaluation of relevant chemical markers that can be connected to specific quality, safety or authenticity aspects of both raw materials\ingredients and corresponding finished products can be effective in the analytical monitoring mitigation scenario [see also Annex 4 of the present document - “Industrial Chemical/Microbiology-PCR-genotyping Markers for Quality and Authenticity”]: these tools can provide information about: (i) targeted analyses able to reveal the presence of markers to detect specific frauds/contaminations; (ii) untargeted analyses, which “see” whole composition of a sample; (iii) the ways to combine them together to control the product in the most accurate way]. In analytical actions, depending on the specific fraud issue, it has to be explored: (i) the potential/effectiveness/repeatability/reproducibility and reliable performance criteria of profiling/fingerprinting/targeted or non-targeted methods on industrial production chain, (ii) the potential/effectiveness (levels of adulteration which can be detected and in what ingredients/food matrix combinations) of rapid screening high-throughput technologies on industrial production lines, evaluating also their performance criteria for detection of frauds/adulterations and discrimination ability applied to different food\raw materials origins (e.g. PDO, PGI,…), production methods (e.g. organic vs traditional, handmade...), treatments and\or processing (e.g. heating, high pressure,...).

3.1 Validation of Non-Targeted Methods
A Guideline for the validation of non-targeted methods in food authenticity and traceability has been developed within FoodIntegrity Work Package 18. The aim of WP18 has been to provide good practices and methodological guidelines for the development and the validation of non-targeted analytical methods for the classification of food commodities. The document takes into account previously published validation proposals and position papers, as well as it is based on observations obtained from research activities carried out during the course of the FoodIntegrity Project:
- A general guideline combining together all analytical techniques and data analysis methods struggles in providing a clear workflow, given the multitude of possibilities
- The purpose of the analysis needs to be carefully set before starting. Classification methods are probabilistic, therefore absolute certainty cannot be sought
- The reliability of the results is mainly influenced by the representativeness of the sample. A minimum number of food samples cannot be identified, since it is strictly case dependent
- Differently from targeted methods, non-targeted approaches can hardly be carried out by a single analyst. Collaboration between experts in the field of analytical chemistry and mathematicians is of utmost importance
- Processed data can be analyzed using different mathematical tools, their performances need to be evaluated to accept the outcome. Levels of acceptability can be set by the analyst according to the initial purpose
- Inter-laboratory validation is still an issue for the majority of the analytical techniques, given the lack of reproducibility occurring among different instruments
- Validated non-targeted methods are prone to expiration, in order to maintain their validity they require a constant update, and re-validation steps need to be scheduled
The guidance aims to be generally applicable to different types of foods and analytical problems (evaluation of integrity, assessment of geographical origin, production procedure and so on), as well as to different analytical techniques coupled to different chemometrics tools. Four main bodies can be identified, such as:

1. The planning of the study (where the main purpose and the sampling plan need to be decided)
2. The feasibility study (a pilot study with a limited number of samples providing the indications needed for the main study)
3. The development of the method (intended as both analytical and mathematical)
4. The validation (first internal, then external with a new set of known samples). Compared to previously proposed guidelines, the feasibility study proposed holds a particular importance, addressing not only the setting up of the analytical protocol but also a pilot chemometric analysis. Moreover, specific counteractions in case of failure during the validation steps are proposed. Finally, the validated method needs to be monitored, updated and occasionally re-validated, upon the arrival of new information describing the class of interest.
3.2 Food Integrity Network

Work package 1 established a Network of over 340 participants from 53 countries, available for consultation and classified in analytical/industrial/chain field of expertise. 7 Stakeholder Derived Open Access Scientific Opinions and correspondent Videos based production. Educational/Training Videos on Fi YouTube Channel to be distributed via website, newsletter, social media, etc.

3.3 Food Integrity Knowledge Base / Handbook / Standards for consistent reporting

Work package 2 designed and built a knowledge base gathering more than 300 methods for checking authenticity of food products. Entries link food product and their potential frauds or integrity issues to appropriate analytical strategies that can be used for food fraud detection or authenticity testing [see also examples in Annex 3].

Service for the industry

The main service provided by the FI_KB will be a reference portal on analytical methods for countering food fraud. Several types of users will find an interest in the FI_KB.

Food industry:

- In the case where a company is facing an adulteration, it can identify an analytical solution for testing samples;
- For preparing a control plan tailored to its needs and relevant for the food matrices.

Laboratories and academia:

- The FI_KB will be used for implementing new methods in their organisations, which will disseminate knowledge against food fraud;
- To access authentic and standardised datasets of analytical methods which can be reused lead to future development of new methods.

All stakeholders:

- Use as a knowledge reference in the field of food fraud, for instance for helping in gap analyses.

Furthermore, a handbook on food authenticity issues and related analytical methods has been written by a group of nearly 50 experts, mainly directly related to Food Integrity project experts: it includes 21 chapters on dedicated food products and a last chapter on food fraud risk mitigation tools. Finally a standard for consistent reporting, comparison and integration of analytical data been established. The aim of this deliverable is to establish a set of guidelines for the production and use of authenticity data, including minimum requirements for meta-data used for the interpretation of analytical results. The Knowledge Base has been transferred to the Joint Research Centre, who will store, maintain and use it in its activities such as watch system on food fraud, method standardisation or research in the field of food fraud. The base will be open to the public, who will be able to access all the methods and also propose new ones.

3.3 Food Fraud Related News Stories Worldwide Repository

Along with a study on the scope of seafood misdescription in the European HORECA-sector and development of methods for authentication based on analysis of recorded data, one of the major outcomes of Work Package 6 is a database of food fraud related news stories worldwide. To automate the process of finding news stories, a web crawler has been developed. A web crawler is an automated software that searches the web for content based on certain keywords. The news stories picked up by the web crawler are transferred to the FARNHub (The Food Authenticity Research Network Hub) which
acts as the final database. The FARNHub was developed through the EU-funded network project Authent-Net, and can be accessed through http://farnhub.authent.cra.wallonie.be/. This platform is an open access web-based portal where users can get an overview of the latest country- and sector-specific food authenticity resources as well as information on publications, reports, projects, new stories, regulations and analytical methods.

3.4 Food Integrity Industrial Integration Infographics & Video tutorials
A complete set of infographics in different European languages concerning foods, risks, analyses and specific case studies has been developed by Work Package 10 and is available online through FI channel. They give an insight on how to work in both rapid screening and confirmatory analysis directions, exploring the potential/performance/effectiveness of a number of profiling/fingerprinting/targeted or non-targeted methods & rapid screening high-throughput technologies, also combined with multivariate approaches. An Industrial Integration video-tutorial, beside other parallel educational video-cartoons, is also available: 12 minutes to give a look into our work, what we have done, and how our project can help food industries to protect their business from frauds, hence strengthening the European food supply chain and assuring the circulation of authentic and reliable products. Industry guidelines & toolboxes relevant for the different stakeholders/food chains are indicated for further evaluations through the links and documents present into the FoodIntegrity website.

3.5 Audits to suppliers
A complimentary part of the mitigation strategy is surely related to stable audits to suppliers in every specific food chain and a special effect can be obtained rationalizing the so-called non-announced audits; a good example on how to conduce those kind of audits can be retrieved by the International Food Standard [IFS Food version 6 Audit protocol for unannounced audits Version 1 February 2016 Documents Templates available at: https://www.tuvaustriaheles.gr/content/IFS_Food_unannounced_audit.pdf].

Specific audit process for multi-location companies with central management
If defined processes are centrally organized in a company with several production sites (e.g. purchasing, personnel management, complaint management, etc.):
– The central managing site – headquarters – shall be audited announced or unannounced. The audit shall always take place before the audit of each production site and shall be performed before the start of the unannounced audit time window of the production site audits.
– The production sites shall be audited unannounced.

The company should prepare a minimum set of documents to be provided to the auditor.
After arrival and introduction, the auditor may briefly review the documents prepared by the company and shall immediately start the audit on the location (production area). The opening meeting and documentation audit shall be undertaken later during the audit.
If, during the unannounced audit, some lines are not operating and involve different HACCP plans, product and technical scopes, an additional audit of the lines, when operating, is mandatory. When performing the audit, two options are possible: – If it is possible, the auditor can ask the company to run the production line(s) later during the first audit day or the following audit day(s), so that the line(s) is/are assessed later during the unannounced audit. – If it is not possible for the company to start the production line(s) during the audit, the auditor shall come back to audit the line(s) when operating, during an extension audit (if the company wants to include these products into the audit scope and/or an exclusion is not possible). The extension audit shall be performed announced.
INDUSTRIAL FOOD FRAUD PREVENTION/ACTION MODEL DEVELOPMENT SCHEDULE:

INDUSTRIAL FOOD FRAUD PREVENTION/ACTION MODEL DEVELOPMENT PROCESS:
INDUSTRIAL FOOD FRAUD PREVENTION/ACTION MODEL:
STRUCTURE A COUNTER FRAUD PROCESS

TSI: Team (of) Scientific Investigation

- Scout new technologies to reveal food frauds
- Define unconventional testing to prevent food frauds
- Suggest new parameters to be monitored specifically for food frauds
- Review vulnerabilities
- Provide info on risky supply chain/suppliers

INDUSTRIAL FOOD FRAUD PREVENTION/ACTION MODEL:
LEARNINGS AFTER MODEL APPLICATION

To prevent frauds you need:
- Specific competences/role in the team
- Auditing program on sub suppliers
- Specific control plans with conventional/unconventional analysis
- To question even your good, long and trusted relationship with suppliers
4. General Conclusions & Key Learnings

• Fraud is an old, big issue. We are at the beginning of a long journey

• Major risks industry-related to food frauds
  • For the consumer:
    - Immediate or long-term health issues
    - Unintentional consumption contrary to particular ethical / religious beliefs
    - Financial loss (purchase of overpriced, adulterated or damaged goods).
  • For food business stakeholders:
    - Decrease of consumers’ confidence in the whole sector
    - Damaged reputation
    - Finance loss purchase overpriced adulterated/damaged products/ingredients

• Industry have firstly to put in place effective systems and strategies to minimize the risk of buying fraudulent raw materials, especially focusing on supply chains that present the highest vulnerability within their activity

• Prioritize «highly vulnerable» supply chains doesn’t mean forgetting core business chains

• We could see a pre-competitive collaboration and data sharing inside the market; this is in part due to the fact that food itself is becoming more and more “global”. In this sense it becomes essential to exploit new informatics frontiers (innovative digital tools and technologies) to set media/scientific-monitoring & early warning solutions

The future scenario will imply the implementation of a Food Frauds Risk Assessment & Action Plan Strategy for each company, depending on food chains involvement, deeply illustrated above and here summarized briefly as:

1. Map each step of the supply chain and identify points of vulnerability
2. Evaluate: (i) purchase volumes & communication (brand relevance), (ii) price volatility; historical documented dangerous evidences or rumors for each supplier
3. Exploit network of associations & official databases knowledge at national/international levels
4. Visit on field of the relevant supply chains; identify external experts of each specific chains; make real scouting of external auditors with expertise on frauds;
5. Identify potential frauds (evaluating opportunity/motivation) and assess the risk
6. Use mass balancing as a mechanism for supply chain transparency & frauds prevention-detection
7. Apply Process Flow Diagrams protocols especially when dealing with complex foods production, measuring & targeting critical process parameters and attributes
8. Identify markers/analysis and reliable analytical/paper trail techniques (rapid/confirmatory & conventional/non-conventional testing)
9. Define a mitigation plan
10. Plan stable non-announced audit schemes as complimentary part of the mitigation strategy
11. Periodically revise priorities/model adjustment/takeout sharing/accountabilities and budget allocation.
There is the need to increase the level of “Awareness” (what are food frauds – what is their origin – what are effective ways to discover them – what are the right databases to be consulted - what can be proposed to anticipate the next one…) in all the stages of the food chains stakeholders.

Acknowledgements
A final acknowledgement has to be strongly reported for all the Industrial Integration Work Package 10 FoodIntegrity partners and also to the entire Consortium and particularly to all the WorkPackage Leaders for their contributions.
ANNEX 1

Food fraud occurs when products are deliberately:
- Diluted
- Mislabeled or misrepresented
- Tampered with
- Substituted with another product

Some of the most fraudulent foods:
- Olive oil
- Milk
- Honey
- Saffron
- Orange juice
- Coffee
- Apple juice
- Tea
- Fish
- Pepper

56% of people say they’re confident that what they’re buying is exactly what is stated.

92% say it’s important that local authorities test food to make sure it is labelled correctly.

Why products are counterfeited:
- Profit
- Cheap and/or easy to copy
- Unsatisfied market demands
- Difficulties in detection and proof

The cost of food fraud:
- Fraud costs the UK food & drinks industry £1bn per year
- Fraud contributes 5p to the price of a £1 loaf of bread...
- ...and 16p to the cost of a pint of beer
- Fraud costs consumers £424 per household per year

The benefits of tackling food fraud:
- Industry could boost profitability by £4.4bn by tackling fraud
- Cutting fraud could make companies more competitive
- Cost of groceries could be reduced by as much as 5p in the £1
- It is safer for consumers

Sources:
- http://www.fsa.gov.uk
- http://www.which.co.uk/campaigns/meat-takeaways-housemeat/know-the-issue
ANNEX 2

Food Authenticity: Five steps to help protect your business from food fraud – FDF UK
http://www.fdf.org.uk/foodauthenticity.aspx 1/5

This simple guide, which follows on from FDF’s Guide on ‘Sustainable Sourcing: Five Steps Towards Managing Supply Chain Risk’, sets out a step by step process to help food and drink manufacturing businesses of all sizes protect their businesses from food fraud by helping them to identify, prioritize and manage upstream supply chain authenticity risks.

Step 1: Map your supply chain
Step 2: Identify impacts, risks & opportunities
Step 3: Assess & prioritise your findings
Step 4: Create a plan of action
Step 5: Implement, track, review & communicate

Step 1: Map your supply chain
Collect information to describe your supply chain on a product basis from a food authenticity perspective

Questions to consider:
- What is required to produce the product, e.g. raw ingredients, water, packaging, transport?
- Who are your immediate suppliers?
- Who supplies them? Think about suppliers all the way back to source.
- Are you changing a supplier or process?
- From which countries are key resources sourced and what do you know about them? e.g. are there any geopolitical issues?
- What are the critical resources for your business?
- What gives the product and its ingredients their value?
- What specific ingredient requirements do you have, eg organic, halal, geographical origin, fair trade?
- On what basis do you buy the ingredients (e.g. are any traded on a specific property such as color or nitrogen content?)
- Have you considered seasonality of supply?

Getting started:
Use expertise from both within your business and outside, such as your trade association and other intelligence sharing networks, to help gather the relevant information.
Start by mapping major product categories i.e. those that are most critical for your business
Gather information from suppliers to identify those who are most at risk (e.g. via questionnaire and supplier assurance and audit processes).
Create a visual and statistical map of your product supply chain.

Step 2: Identify impacts, risks & opportunities
Understand the key risks and opportunities for food fraud in your supply chain

Questions to consider
- Is anything that you are sourcing in short supply and/or the subject of media or other concern?
- Have there been changes in the products, processes or supply chains your business depend on?
- Are your supplier assurance and audit systems fit for purpose?
- What are the risks to your business, market presence, and reputation?
- Are there possibilities to do things differently (try to imagine the mindset of those who may seek to commit food fraud)?
- Is a supplier or potential supplier offering you a deal which seems 'too good to be true'?
- Can you identify any other changes to the ingredients, processes or supply chains that can constitute a risk?
- Does your own production process add any further risks?

**Getting started**

Make sure you are aware of the main factors which may impact on your supply chains (i.e. economic and seasonal variables)

Identify resources that could be the target of fraud because of their value or associated sensitivities

Think about key materials and whether there is any history of authenticity problems

Conduct scenario planning: consider the risk if certain resources were to become unavailable or to be substituted?

Gather information from suppliers on identified supply chain risks, including whether they have action plans in place

Include in your risk assessment information from other sources, such as your trade association and other intelligence sharing networks

Continuously monitor in real time for changes to risks in the supply chain (e.g. environmental and economic changes which may affect supply chain)

**Step 3: Assess & prioritise your findings**

Analyse how your business can manage food authenticity related risks and take advantage of opportunities to limit food fraud

**Questions to consider:**

- What are your key risks and who are the associated suppliers?
- Have you prioritised supplier risk separately, e.g. type of supply chain, direct or indirect suppliers, outsourced?
- How well do you know your suppliers, e.g. how long have you been dealing with them and what is their track record like?
- How can you learn more about them, e.g. partnerships, supplier schemes?
- Are your processes for appointing new suppliers robust?
- Do you have full visibility of your supply chain?

**Getting started**

Ensure strong links between procurement and regulatory/technical teams to help monitor and assess the key risks and potential opportunities for food fraud

Ensure you are using your supplier assurance and audit systems to help you to assess and prioritise supplier risk

To help assess risks, make the most of external sources of information, e.g. your trade association

Create a risk matrix (e.g. changes in regulatory requirements, supply and demand imbalances, resilience of supply chain, documented cases of fraud) to help with prioritisation

Assess what is business essential

Make sure you know what you are buying, have agreed specifications and monitoring and compliance checks in place

In your supplier assurance systems, be aware of the need to keep under scrutiny the possibility of your suppliers outsourcing to third parties

**Step 4: Create a plan of action**

Define a set of actions to reflect the risk of food fraud and prioritise the opportunities to limit it already established

**Questions to consider:**
- How can the identified risks be mitigated?
- What measures are feasible to address the priority risks?
- Who is responsible for delivering the different parts of the plan?
- How can you get support from senior management to address these actions and incorporate into company strategy?
- How best can you involve your suppliers?
- What are your success criteria?

**Getting started**
Consider the effectiveness of your chosen supplier assurance systems in limiting the opportunities for food fraud and mitigating the risk from authenticity issues (including prioritisation of supplier risks)
Consider the role of authenticity testing
Set up internal communications to explain why you are doing this and what is expected of colleagues (let all know that their views and observations are welcome)
Set up meetings with suppliers about the risks you have prioritised and explain what you would like to achieve
Ensure senior management signoff of the company's strategy. Consider using external expertise, particularly to address risks where you have no immediate solution

**Step 5: Implement, track, review and communicate**
Ensure action is taken, progress tracked, and communicated

**Questions to consider:**
- What is required to implement the action plan with suppliers?
- How best can you measure and report progress to senior management and across the broader organisation?

**Getting started**
Consider integrating relevant parts of the action plan into your supplier assurance and audit systems
Agree a timetable for reviewing the action plan and regularly check it is on track
Make sure all employees involved have the support and resources they need consider any company training needs
Consider broader internal communication and opportunities for external communications to enhance transparency and support
Think of all five steps as a cyclical process that needs to be reviewed and repeated on a regular basis, as well as in response to substantial changes in the supply chain, to ensure that it remains current
Continue to gather real time data and horizon scan for substantial changes in the supply chain which should trigger a process review (horizon scanning process involves cross-functions, site-customer quality-regulatory-purchasing-trade stably monthly updating and interconnection).
Implement the lessons learnt back into business operations, e.g. for new products and processes

**Help for small businesses**
If you are a smaller business and don't know where to start, try answering a few basic questions:
- What are your key raw materials?
- Where do they come from?
- How resilient is their supply chain?
- How do you protect your business from food fraud?

Above all THINK RISK and PLAN AHEAD!
ANNEX 3

Choose from a drop down menu

Optionally select fraud types

And/or issues

Then click Get Results

Figure 3: Number of entries per food commodity.


## Annex 4

### Industry Chemical Markers for Quality-Authenticity

Selection/evaluation of relevant chemical markers from the industrial perspective, which can be connected to specific quality/authenticity aspects of both raw materials/ingredients and corresponding finished products.

<table>
<thead>
<tr>
<th>RAW MATERIAL/INGREDIENT/PRODUCT</th>
<th>TYPE OF RISK (fraud, sophistication, contamination)</th>
<th>TYPE OF ANALYSIS USUALLY ADOPTED</th>
<th>CHEMICAL MARKERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee</td>
<td>Blending with different coffee species</td>
<td>HPLC-DAD; LC-MS; LC-ECD; GC-HRMS</td>
<td>Chlorogenic acids determination; Unsaponifiable diterpenes and sterols fraction characterization</td>
</tr>
<tr>
<td></td>
<td>Sugars addition (soluble coffee)</td>
<td>LC-MS/IR/IEC</td>
<td>Saccharides profiles</td>
</tr>
<tr>
<td></td>
<td>Origin mislabeling</td>
<td>IRMS; ICPMS</td>
<td>Stable isotope ratio $^{13}$H/$^{1}$H, $^{87}$Sr/$^{86}$Sr, Trace elements profile</td>
</tr>
<tr>
<td>Cocoa products, chocolate-chocolate compounds</td>
<td>Addition of vegetable fats different from cocoa butter or hydrogenated fats</td>
<td>GC-MS; DART-HRMS</td>
<td>Fatty Acids/Triglycerides profiles</td>
</tr>
<tr>
<td></td>
<td>Contamination: presence of cocoa shells over 5%</td>
<td>GC-FID; GC-MS</td>
<td>Fatty acid tryptamides</td>
</tr>
<tr>
<td>Eggs/Egg products</td>
<td>Addition of artificially colored eggs</td>
<td>HPLC-DAD; LC-MS</td>
<td>Extraneous pigments molecules. For instance, several banned dyes can be detected with a multiresidues method (e.g.: sudan, para red, toluidine red,...)</td>
</tr>
<tr>
<td></td>
<td>Apparent increase of the protein content/dry matter</td>
<td>LC-MS</td>
<td>Melamine</td>
</tr>
<tr>
<td></td>
<td>Apparent increase of fat content</td>
<td>GC-FID; GC-MS</td>
<td>Mineral/vegetable oils profile</td>
</tr>
<tr>
<td>Food Product</td>
<td>Issue</td>
<td>Method(s)</td>
<td>Detection Features</td>
</tr>
<tr>
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</tr>
<tr>
<td>Eggs/Egg products</td>
<td>Addition of incubated and/or not fresh eggs</td>
<td>Enzymatic methods; HPLC; E-Nose</td>
<td>Organic acids such as 3-OH Butyric acid, Succinic Acid, Lactic Acid, ...</td>
</tr>
<tr>
<td></td>
<td>Use of synthetic fertilizers in organic agriculture</td>
<td>IRMS</td>
<td>Stable isotope ratio of N ($^{15}$N/$^{14}$N)</td>
</tr>
<tr>
<td></td>
<td>Temperature abuse during and/or after harvest</td>
<td>ELISA; HPLC</td>
<td>Histamine &amp; other biogenic amines</td>
</tr>
<tr>
<td></td>
<td>Mislabeled</td>
<td>IRMS</td>
<td>Stable isotope ratios $^2$H/$^1$H, $^{13}$C/$^{12}$C, $^{15}$N/$^{14}$N, $^{34}$S/$^{32}$S</td>
</tr>
<tr>
<td></td>
<td>Adulteration/substitution with different species</td>
<td>ELISA; LC-MS</td>
<td>Specific protein markers</td>
</tr>
<tr>
<td>Fish</td>
<td>Sugar addition (sugars, carbohydrate sweeteners e.g. HFCS, IS,...)</td>
<td>LC-MS/IR/IEC; GC; IRMS; SNIF-NMR</td>
<td>Saccharides profiles; Oligosaccharide profile; Stable isotope ratio of C ($^{13}$C/$^{12}$C) and H ($^2$H/$^1$H) in ethanol from sugars (AOAC methods 2004.01 and 995.17)</td>
</tr>
<tr>
<td></td>
<td>Water addition</td>
<td>IRMS</td>
<td>Stable isotope ratio of O ($^{18}$O/$^{16}$O) and of H ($^2$H/$^1$H) in water</td>
</tr>
<tr>
<td></td>
<td>Addition of citric-malic-ascorbic-tartaric acids</td>
<td>Enzymatic methods; HPLC; IRMS</td>
<td>Organic acids profiles; Stable isotope ratio of C ($^{13}$C/$^{12}$C)</td>
</tr>
<tr>
<td></td>
<td>Addition of other cheaper fruits</td>
<td>HPAEC-PAD; GC-FID LC-MS</td>
<td>Polyphenols, Anthocyanins, Polymethoxylated flavones (PMFs), Carotenoids profiles</td>
</tr>
<tr>
<td></td>
<td>Addition of synthetic aroma</td>
<td>Chiral GC, GC-IRMS</td>
<td>Racemic mixtures in the aroma/flavor profile</td>
</tr>
<tr>
<td></td>
<td>Geographical origin</td>
<td>IRMS, TIMS</td>
<td>$^{87}$Sr/$^{86}$Sr-TIMS and multi-isotope testing</td>
</tr>
<tr>
<td>Honey</td>
<td>Adulteration of acacia honey with rape one</td>
<td>HPLC-DAD; LC-MS; LC-ECD</td>
<td>Chlorogenic acid and ellagic acid</td>
</tr>
<tr>
<td></td>
<td>False floral origin</td>
<td>ICPMS; IRMS</td>
<td>Trace elements profile; Stable isotope ratios of C ($^{13}$C/$^{12}$C) and H ($^2$H/$^1$H)</td>
</tr>
<tr>
<td>Food Category</td>
<td>Example Activity</td>
<td>Methodology</td>
<td>Analysis Results</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
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<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Honey</td>
<td>Addition of exogenous sugar</td>
<td>IRMS</td>
<td>Stable isotope ratios of C (^{13}\text{C}/^{12}\text{C}) in honey and protein (AOAC 998.12)</td>
</tr>
<tr>
<td>Meat</td>
<td>Substitution of fresh meat with frozen-thawed one</td>
<td>Enzyme activity assay</td>
<td>Beta-hydroxacyl-CoA dehydrogenase activity</td>
</tr>
<tr>
<td></td>
<td>Mislabling; origin mislabeling</td>
<td>IRMS; ICPMS</td>
<td>Stable isotope ratios (^2\text{H}/^{1}\text{H}, ^{13}\text{C}/^{12}\text{C}, ^{15}\text{N}/^{14}\text{N}, ^{34}\text{S}/^{32}\text{S}) Trace element/mineral profiles</td>
</tr>
<tr>
<td></td>
<td>Adulteration/substitution with different species</td>
<td>ELISA; LC-MS</td>
<td>Specific protein markers</td>
</tr>
<tr>
<td>Milk and Derivatives; Cheeses</td>
<td>Substitution of natural mozzarella cheese with imitation</td>
<td>HPLC</td>
<td>Lysinoalanine</td>
</tr>
<tr>
<td></td>
<td>Apparent increase of the protein content/dry matter</td>
<td>LC-MS</td>
<td>Melamine</td>
</tr>
<tr>
<td></td>
<td>Substitution of PDO cheese with others</td>
<td>HPLC; GC; LC-MS; IRMS; ICPMS</td>
<td>Stable isotope ratios (^2\text{H}/^{1}\text{H}, ^{13}\text{C}/^{12}\text{C}, ^{15}\text{N}/^{14}\text{N}, ^{34}\text{S}/^{32}\text{S}) Trace element profile</td>
</tr>
<tr>
<td></td>
<td>Addition of other “non-milk” fats/oils</td>
<td>GC-MS; DART-HRMS</td>
<td>Fatty Acids/Triglycerides profiles</td>
</tr>
<tr>
<td></td>
<td>Addition of pigments (e.g. beta-carotene,...) in order to increase color</td>
<td>HPLC-DAD</td>
<td>Carotenoids profile</td>
</tr>
<tr>
<td>Oils &amp; Fats</td>
<td>Addition of foreign/refined/deodorized/... oil to EVO</td>
<td>GC-MS; LC-MS; IRMS</td>
<td>Fatty Acids/Triglycerides profiles; Stable isotope ratio of C (^{13}\text{C}/^{12}\text{C}) and H (^{1}\text{H}/^{2}\text{H}) Chlorophylls, pheophytins, carotenoids (…) profiles</td>
</tr>
<tr>
<td></td>
<td>Addition of pigments in order to improve the color</td>
<td>HPLC-DAD; LC-MS</td>
<td>Stable isotope ratios (^{13}\text{C}/^{12}\text{C}, ^{1}\text{H}/^{2}\text{H}, ^{16}\text{O}/^{18}\text{O})</td>
</tr>
<tr>
<td></td>
<td>Mislabling</td>
<td>IRMS</td>
<td>Stable isotope ratios (^{13}\text{C}/^{12}\text{C}, ^{1}\text{H}/^{2}\text{H}, ^{16}\text{O}/^{18}\text{O})</td>
</tr>
<tr>
<td><strong>Wine; Vinegar</strong></td>
<td><strong>Addition of cheaper sugar/alcohol</strong></td>
<td>GC-FID/MS; LC-MS/IR/IEC IRMS, SNIF-NMR</td>
<td>Saccharides &amp; Alcoholic profiles; Stable isotope ratio of C ($^{13}$C/$^{12}$C) and H ($^{1}$H/$^{2}$H) in ethanol and acetic acid (methods OIV-MA-AS311-05 and OIV-MA-AS312-07; OIV 510/2013, EN 16466-1 and EN 16466-2)</td>
</tr>
<tr>
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</tr>
<tr>
<td><strong>Addition of water</strong></td>
<td>IRMS</td>
<td>Stable isotope ratio of O ($^{18}$O/$^{16}$O) in water (OIV-MA-AS2-12; OIV 511/2013 and EN 16466-3)</td>
<td></td>
</tr>
<tr>
<td><strong>Addition of industrial CO2</strong></td>
<td>IRMS</td>
<td>Stable isotope ratio of C ($^{13}$C/$^{12}$C) in CO2 (OIV-MA-F-AS314-03-CO2MOU)</td>
<td></td>
</tr>
<tr>
<td><strong>Geographical origin</strong></td>
<td>IRMS, SNIF-NMR</td>
<td>Stable isotope ratio of C ($^{13}$C/$^{12}$C) and H ($^{1}$H/$^{2}$H) in ethanol and acetic acid and stable isotope ratio of O ($^{18}$O/$^{16}$O) in water</td>
<td></td>
</tr>
</tbody>
</table>

| **Vegetables** | **Use of synthetic fertilizers in organic agriculture** | IRMS | Stable isotope ratios of N ($^{15}$N/$^{14}$N) in bulk tissue and of O ($^{18}$O/$^{16}$O) in plant derived nitrate |

| **Vanilla extracts** | **Substitution of natural vanilla flavor with artificial ones** | GC-MS | 4-hydroxybenzaldehyde |
| **Addition of exogenous vanilla** | GC-IRMS | Stable isotope ratio of C ($^{13}$C/$^{12}$C) (AOAC 2006.05) |

| **Spirit Drinks** | **Addition of water** | Density; IRMS | Ethanol/Water; Stable isotope ratio $^{18}$O/$^{16}$O and $^{2}$H/$^{1}$H in water |
| **Addition of neutral alcohol/non-potable alcohol/cheaper alternative spirits** | GC-FID; GC-MS; LC-UV | Volatile congener profiles, and maturation related compounds (for matured products) |
| **Addition of sweeteners and flavourings** | LC-IEC; GC-MS; LC-UV | Sugar profiles and flavour compounds |
**Quality-Authenticity: microbiology, PCR, genotyping**

Selection/evaluation of markers from the industrial perspective, which can be connected to specific quality/authenticity aspects of both raw materials/ingredients and corresponding finished products.

<table>
<thead>
<tr>
<th>RAW MATERIAL/ INGREDIENT/PRODUCT</th>
<th>TYPE OF RISK (fraud, sophistication, contamination)</th>
<th>POSSIBLE TYPE OF ANALYSIS</th>
<th>MOLECULAR MARKERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee</td>
<td>Blending with different coffee species</td>
<td>PCR genotyping; Real time-PCR (allele-specific probes)</td>
<td>SNPs, cpDNA, sequencing</td>
</tr>
<tr>
<td>Cocoa</td>
<td>Quality of fermentation</td>
<td>PCR-DGGE, PCR-RAPD of fermenting bacteria</td>
<td>16S and 23S rDNA</td>
</tr>
<tr>
<td>Olive oil</td>
<td>Adulteration/substitution with different species</td>
<td>barcoding, PCR amplification and High Resolution Melting (HRM) analysis, SSCP</td>
<td>cpDNA (rbcl)</td>
</tr>
<tr>
<td></td>
<td>Compliance with PDO, mislabeling</td>
<td>genotyping with molecular markers, PCR-RFLP, sequencing</td>
<td>SNPs, microsatellites</td>
</tr>
<tr>
<td>Mislabling</td>
<td></td>
<td>PCR-FINS; PCR genotyping; Real time-PCR (allele-specific probes); barcoding</td>
<td>Sequencing, SNPs, mtDNA (COX1, 16S rDNA)</td>
</tr>
<tr>
<td>Adulteration/substitution with different species</td>
<td></td>
<td>PCR-FINS; PCR genotyping; Real time-PCR (allele-specific probes); barcoding</td>
<td>Sequencing, SNPs, mtDNA (COX1, 16S rDNA, CYTB)</td>
</tr>
<tr>
<td>Addition of other cheaper fishes</td>
<td></td>
<td>PCR-FINS; PCR genotyping, RT-PCR (allele-specific probes)</td>
<td>Sequencing, SNPs</td>
</tr>
<tr>
<td>Geographical origin</td>
<td></td>
<td>PCR genotyping, Real time-PCR (allele-specific probes)</td>
<td>SNPs</td>
</tr>
<tr>
<td>Category</td>
<td>Issue/Activity</td>
<td>Techniques</td>
<td>Sequencing, Other Genotyping markers</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>Meat</td>
<td>Mislabeling</td>
<td>PCR-FINS; PCR genotyping, Real time-PCR (allele-specific probes); barcoding</td>
<td>Sequencing, SNPs, mtDNA</td>
</tr>
<tr>
<td>Adulteration/substitution with different species</td>
<td>PCR-FINS; PCR genotyping; Real time-PCR (allele-specific probes); barcoding</td>
<td></td>
<td>Sequencing, SNPs, mtDNA</td>
</tr>
<tr>
<td>Addition of other cheaper meats</td>
<td>PCR-FINS; PCR genotyping; Real time-PCR (allele-specific probes)</td>
<td></td>
<td>Sequencing, SNPs</td>
</tr>
<tr>
<td>Geographical origin of fermented meat products, and compliance with PDO</td>
<td>PCR genotyping of bacterial communities with PCR-DGGE or PCR-RAPD, sequencing</td>
<td></td>
<td>DGGE or Sequencing 16S rDNA</td>
</tr>
<tr>
<td>Compliance with Halal or Kosher practices</td>
<td>Barcoding, Real time-PCR (allele specific probes)</td>
<td></td>
<td>mtDNA (CYTB, COX1, 12S rDNA)</td>
</tr>
<tr>
<td>Milk and Derivatives; Cheeses</td>
<td>Adulteration/substitution with different species</td>
<td>Primer specific-RT PCR; barcoding</td>
<td>DNA sequence; mtDNA (CYTB, 12S rDNA) or casein</td>
</tr>
<tr>
<td>Substitution of PDO cheese with others</td>
<td>PCR genotyping, Real time-PCR (allele-specific probes) (when PDO based on breeds)</td>
<td></td>
<td>SNPs</td>
</tr>
<tr>
<td>Geographical origin of fermented milk products, and compliance with PDO</td>
<td>PCR genotyping of bacterial communities with PCR-DGGE or PCR-RAPD, sequencing</td>
<td></td>
<td>DGGE or Sequencing 16S rDNA</td>
</tr>
<tr>
<td>Cereals</td>
<td>Mislabling of species (coeliac disease)</td>
<td>Real time-PCR</td>
<td>nuclear genes for rDNA</td>
</tr>
<tr>
<td>Adulteration with different species or cultivars in PDO products</td>
<td>genotyping for cultivar identification</td>
<td></td>
<td>microsatellites, SNPs in gliadin genes, other specific genes</td>
</tr>
</tbody>
</table>
