

European Metrology Network for Safe and Sustainable Food

Strategic Research Agenda
Version 1.0 (09/2024)



**SAFE AND
SUSTAINABLE FOOD**

Authorship and Imprint

This document was developed by the EURAMET e.V., European Metrology Network (EMN) for Safe and Sustainable Food.

Authors: Fatma Akçadag (UME, TR), Roland Becker (BAM, DE), Erika Bester (MIRS/ZRS Koper/LAB-IZO, SI), Dmytro Chupis (SE "Ukrmetrteststandard", UA), Ana Curdov (INM-MD, MD), Philip Dunn (LGC, UK), Marie-Pierre Jaffrezic (LNE, FR), Aida Jotanovic (IMBiH, BA), Elias Kakoulides (EXHM/GSCL-EIM, GR), Ivo Leito (UT, EE), Silvia Mallia (METAS, CH), Mojca Milavec (MIRS/NIB/FITO, SI), Gavin O'Connor (PTB, DE), Nives Ogrinc (MIRS/IJS/F-2,O-2, SI), Jan C. Petersen (DFM, DK), Chiara Portesi (INRiM, IT), Caroline Pritchard (LGC, UK), Andrea M. Rossi (INRiM, IT), Marjana Savic (IW, BA), Michal Strzelec (GUM, PL) on behalf of the EMN for Safe and Sustainable Food with input from the EMN Members BAM (DE), DFM (DK), EXHM/GSCL-EIM (GR), GUM (PL), IMBiH (BA), INM-MD (MD), INRiM (IT), IW (BA), LGC (UK), LNE (FR), METAS (CH), MIRS/IJS/F-2,O-2 (SI), MIRS/NIB/FITO (SI), MIRS/ZRS Koper/LAB-IZO (SI), PTB (DE), SE "Ukrmetrteststandard" (UA), UME (TR), and UT (EE).

Part of this work has received funding from the EMPIR programme (Project 20NET02 '[Support for a European Metrology Network on Food Safety](#)'). The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR participating states.

Version 1.0 (09/2024)

EURAMET e.V.
Bundesallee 100
D-38116 Braunschweig
Germany

E-Mail: secretariat@euramet.org
Phone: +49 531 592 1960

Official language

The English language version of this document is the definitive version.

Copyright

The copyright of this publication (Strategic Research Agenda, European Metrology Network for Safe and Sustainable Food, Version 1.0 – English version) is held by © EURAMET e.V. 2024. The text may not be copied for resale and may not be reproduced other than in full.

ISBN 978-3-942992-94-7

Image on cover page: [istockphoto.com/greenleaf123](https://www.istockphoto.com/greenleaf123)

Further information

This is the first version of the Strategic Research Agenda for EMN for Safe and Sustainable Food, which provides guidance towards metrology needs and the technical challenges that need to be solved as a priority through collaborative efforts between National Metrology Institutes (NMIs), Designated Institutes (DIs) and stakeholders. This document will be revised periodically in accordance with priority changes from the Safe and Sustainable Food community.

No representation is made, nor warranty given that this document or the information contained in it will be suitable for any particular purpose. In no event shall EURAMET, the authors or anyone else involved in the creation of the document be liable for any damages whatsoever arising out of the use of the information contained herein. The parties using the Strategic Research Agenda shall indemnify EURAMET accordingly.

For further information about this document, please contact your national contact person of the EURAMET European Metrology Network for Safe and Sustainable Food (see <https://www.euramet.org>).

TABLE OF CONTENTS

List of Abbreviations.....	2
Executive Summary.....	5
Acknowledgment.....	5
1 INTRODUCTION	6
2 BACKGROUND	6
2.1 Current and future European trends for food safety and sustainability.....	6
2.2 Food safety and sustainability Policies and Strategies	8
2.3 European Metrology Network for Food Safety and Sustainability	10
2.4 Purpose of the document	12
3 STRATEGIC FRAMEWORK: THREE METROLOGICAL PILLARS FOR ENSURING FOOD SAFETY AND SUSTAINABILITY.....	13
3.1 Metrological support to advanced analytical techniques for food safety from farm to fork	13
3.2 Development of metrological traceable certified primary calibrators and matrix reference materials for a sustainable food and feed system	14
3.3 Metrological solutions for a sustainable food system.....	16
4 MEASUREMENT NEEDS.....	18
4.1 Link and dialogue with existing infrastructures	20
4.2 Stakeholder input on measurement needs	20
5 IMPLEMENTATION ROADMAP & PRIORITISATION	22
6 CONCLUSIONS	23
7 REFERENCES	24
8 APPENDIX 1.....	25
9 APPENDIX 2.....	29

List of Abbreviations

AI	Artificial Intelligence
Al	Aluminum
AOAC	Association of Official Analytical Collaboration
As	Arsenic
B	Boron
Ba	Barium
BIPM	International Bureau of Weights and Measures
C	Carbon
CBD	Cannabidiol Compound
CCQM	Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology
Cd	Cadmium
CEC	Contaminants of Emerging Concerns
CEN	European Committee for Standardisation
CMC	Calibration Measurement Capabilities
Cr	Chromium
CRM	Certified Reference Material
DIs	Designated Institutes
EC	European Commission
EFSA	European Food Safety Authority
EMN	European Metrology Network
EMPIR	European Metrology Programme for Innovation and Research
EMRP	European Metrology Research Programme
EU	European Union
EURAMET	European Association of National Metrology Institutes
EURLs	European Union Reference Laboratories
FAIR	Findable, Accessible, Interoperable, Reusable
FIRMS	Forensics Isotope Ratio Mass Spectrometry
FTIR	Fourier-transform Infrared Spectroscopy
GEs	Glycidyl Fatty Acid Esters
GMO	Genetic Modified Organisms
Hg	Mercury
H	Hydrogen
IAEA	International Atomic Energy Agency
IAWG	Inorganic Analysis Working Group
IFCC	International Federation of Clinical Chemistry
IRMS	Isotope Ratio Mass Spectrometer

IRWG	Isotope Ratio Working Group
ISO	International Organization for Standardization
ISO TC 334	ISO Technical Committee 334
IUPAC	International Union of Pure and Applied Chemistry
JNP	Joint Network Project
JRC	Joint Research Centre
LC MS	Liquid Chromatography Mass Spectrometry
LoQ	Limit of Quantification
MC ICP-MS	Multicollector Inductivity Coupled Plasma Mass Spectrometry
3-MCPDs	3-Monochloropropanediol
MoU	Memorandum of Understanding
MOSH	Mineral Oil Saturated Hydrocarbons
MOAH	Mineral Oil Alkylated Aromatic Hydrocarbons
MS	Mass Spectrometry
N	Nitrogen
NAWG	Nucleic acid Analysis Working Group
NIST	National Institute of Standards and Technology
NMIs	National Measurement Institutes
NRLs	National Reference Laboratories
O	Oxygen
OAWG	Organic Analysis Working Group
PAHs	Polycyclic Aromatic Hydrocarbons
PAT	Process Analytical Technology
PAWG	Protein Analysis Working Group
Pb	Lead
PFAS	Polyfluoroalkyl Substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
PRTs	Potential Research Topics
PT	Proficiency Testing
RMs	Reference Material
R&I	Research and Innovation
S	Sulphur
SAWG	Surface Analysis Working Group
Sb	Antimony
Se	Selenium
SEM	Scanning Electron Microscopy
SI	International System of Units

Sr	Strontium
SOPs	Standard Operational Procedures
SRA	Strategic Research Agenda
TC	Technical Committee
TC-MC	Technical Committee of Metrology in Chemistry
TEM	Transmission Electron Microscopy
TGA	Differential Scanning Calorimetry
USGS	United States Geological Survey
VOCs	Volatile Organic Compounds
WHO	World Health Organization
XPS	X-ray Photoelectron Spectroscopy
XRD	X-ray Diffraction

Executive Summary

The European Association of National Metrology Institutes (EURAMET) recognized the strategic importance of food safety and sustainability and approved the network proposal European Metrology Network for Safe and Sustainable Food (EMN Food) which started in September 2022. The primary objective of this network is to formulate a Strategic Research Agenda (SRA), which addresses needs in measurement science and techniques in food safety and sustainability in a coordinated manner through the National Metrology Institutes (NMIs) and Designated Institutes (DIs) of Europe.

This document represents the first version of the Strategic Research Agenda (SRA) for EMN Food. It outlines a vision and ambition for Europe over the coming five to ten years, aiming to coordinate and align national R&D strategies, including smart specialization strategies, through comprehensive stakeholder engagement. Additionally, the document examines current and future trends in food safety and sustainability, highlighting the three metrological pillars:

- Metrological support to advanced analytical techniques for food safety from farm to fork.
- Development of metrological traceable certified primary calibrators and matrix reference materials for a sustainable food and feed system.
- Metrological solutions for a sustainable food system.

Further, it outlines measurement needs and challenges that members and stakeholders in this field, along with metrology specialists, have identified. While some of these challenges have been addressed in the initial JNP project, ScreenFood, others have been identified as ongoing measurement needs. The EMN Food members prioritize these needs as research priorities to ensure they are properly addressed. These efforts pave the way for long-term commitments from all involved parties, leading to an implementation roadmap outlined in the strategic agenda.

The SRA will be revised annually to align with the latest advancements in the field serving as a holistic guide to meet the evolving needs of the food safety and sustainability community.

Let's create ONE VOICE FOR EUROPE to drive METROLOGY in the FOOD SAFETY and SUSTAINABILITY field



**SAFE AND
SUSTAINABLE FOOD**

Acknowledgment

The European Metrology Network for Safe and Sustainable Food is supported by the joint network project 20NET02 Food-MetNet: Support for a European Metrology Network for Food Safety. This document has been developed through that project. The 20NET02 Food-MetNet has received funding from EMPIR. The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States.

1 INTRODUCTION

Safe and high-quality food is the fundamental prerequisite for human health. Food production has evolved considerably during the past decades in many aspects. Relevant changes are being observed in the society: healthier habits and life-styles produce emerging requests for food safety assurance, food quality, and healthy diets in order to prevent human diseases. On the other hand, feeding disorders and diseases arising from incorrect diets and/or low-quality foods consumption are also increasing. Diet diseases cause yearly death of about two million people at the global level, according to the World Health Organization (WHO). This problem is complex and worldwide recognized, as highlighted by the European Commission in the current framework program, Horizon 2020, and by the World Expo Milan 2015 (EXPO 2015: "Feeding the planet").

The EU food policy aims to assure a high level of food safety and animal & plant health within the EU through coherent farm-to-table measures and adequate monitoring, while ensuring an effective internal market. These objectives are pursued by considering three core elements: (i) food safety legislation, (ii) sound scientific advice on which to base decisions (EFSA underpins all EU food and feed policy), and (iii) enforcement and control.

EMN Food Vision

To create a unified platform that connects metrology institutes across various scientific fields to enhance knowledge and address current and future challenges in food safety and sustainability. Through collaboration, we strive to contribute to a safer, healthier, and more sustainable global food supply.

EMN Food Mission

To establish and maintain a comprehensive European metrological network focused on advancing measurement standards in food safety and sustainability. By fostering collaboration among metrology institutes, designated institutes, and stakeholders, EMN Food aims to develop and implement cutting-edge measurement techniques, reference materials, and methodologies. Our mission is to enhance the accuracy, reliability, and harmonization of measurements across the entire food chain, addressing current and emerging challenges in food safety and sustainability.

2 BACKGROUND

2.1 Current and future European trends for food safety and sustainability

In terms of turnover (> €1.2 trillion), added value (€206 billion) and employment (20% of total employment in the EU agriculture sector), the food and beverage industries are the largest manufacturing sector in the European Union (EU). Globally, it is worth over US\$8 trillion and will have to feed an estimate 9.6 billion people by 2050 [24]. Given the industry's size and complexity, it is not surprising that it faces many challenges starting with food safety.

Food safety is directly related to public health and well-being, encompassing a set of practices and regulations designed to ensure that food products are safe for consumption at every stage of the supply chain. It involves the prevention, detection, and management of risks associated with foodborne illnesses, contaminants, and hazards. Rigorous standards and protocols are established to safeguard against biological, chemical, and physical hazards that may compromise the safety of the food we eat. Key components of food safety include proper hygiene practices during food handling and preparation, effective storage and transportation conditions, as well as stringent monitoring and regulatory frameworks. Unsafe food containing harmful bacteria, viruses, parasites or chemical substances causes more than 200 diseases, ranging from diarrhoea to cancers [2].

Addressing a spectrum of challenges, the modern landscape of food safety extends beyond conventional concerns to encompass a multifaceted approach. This includes preventing the spread of plant pathogens, safeguarding against chemical contaminants, nano and microplastics, allergens, and unauthorized genetically modified organisms—all crucial elements in maintaining the safety and integrity of our food supply [3]. Concurrently, a focus on quality assurance, ensuring the authenticity

of food products, becomes paramount in the prevention of food fraud. Further, food fraud, which is defined as the deliberate and intentional substitution, addition, tampering, or misrepresentation of food, food ingredients, or food packaging for the purpose of economic gain costs the industry between €7 billion [4] and €50 billion [5] per year in lost revenues. This threat from food fraud is twofold; first, an uncertain origin of counterfeited food raises the issue of safety, potentially exposing consumers to health and safety risks; second, food-related crime weakens the European economy and can seriously damage a brand's reputation.

Food sustainability

Increases in the global standard of living means that by 2050 the world will require an additional 265 million tonnes of proteins and filling this protein gap will become a major challenge [6]. Solutions will require not only changes in consumer behaviour but will mean embracing new food production technologies and new food i.e. the synthesis of food and feed components from non-food materials or the use of non-traditional resources, such as insects or microalgae. Uncertainties (lack of knowledge), however remain regarding the nutritional quality and hazards of these alternative food and feed sources and there remains few systematically collected data and studies on biological and hazards are scarce, and most scientists agree that much more data is needed.

The future also means living more sustainably and with less food waste. It is estimated that over one third of the food produced every year an amount equivalent to 1.3 billion tonnes is lost or wasted. Food waste amounts to roughly US\$680 billion in developed countries and US\$310 billion in developing countries [7]. In the EU, around 88 million tonnes of food waste are generated annually with associated costs estimated at 143 billion euros and occurs at all stages of the food chain.

At present, the EU is looking for every opportunity to prevent food waste and strengthen sustainability of the food system [8]. By 2030, flows in the global food system will be increasingly circular, thus minimising waste along the supply chain. Advanced materials and new technologies such as nanotechnology will play an important role in solving many of these issues. For example, through novel applications including new and intelligent food packaging system food safety will be improved. As well as benefits, however, adopting new technologies brings unknown risks, for example, exposure to nanomaterials in the human food is bound to occur and new analytical methods are, needed to fully detect and characterise nanomaterials in food.

Nowadays, there are many measurement techniques, analytical methods, reference standards and databases that can be applied in the mention fields to assure food safety. Most of research laboratories, institutes and agencies use independently the available analytical techniques according to their objectives. Due to the absence of harmonized and standardized methods, a number of instruments have been developed, leading to a wide array of results. Unfortunately, this huge information is often inefficient and contradictory. However, a better coordination among institutions can improve the current state of art in food-related measurements at European level. Further, the requirements in food safety might be addressed also through the use of rapid analysis methods and process analytical technology (PAT) [9,10]. In 2004, the Food and Drug Administration defined PAT as a system to design, analyse, and control manufacturing processes through timely measurements of critical material attribute and critical process parameters which affect critical quality attributes. Although the PAT concept was initially derived from the pharmaceutical industry, the importance of product consistency, quality, and process automation has emerged also in the food industry, allowing to move analytics closer to the process for continuous production. Regardless of the certain benefits offered by real-time process control and decentralized analysis, equal attention is required on assuring the robustness and constant accuracy of measurements considering that both analytical methods and analytical systems have to be tested to ensure that they meet the basic requirement to be fit for purpose [11].

Timely data collection and accurate predictive models can substantially reduce issues along the food chain.

Managing big data: The move to the digital world has meant that we can generate and store vast amounts of data. The problem is not just the massive amount of data but that much of it is heterogeneous and treated in isolation. If used ethically, the ability to manage and make sense of this data will have immeasurable benefits for society. The challenge is data normalization, i.e., FAIR (Findable, Accessible, Interoperable, Reusable), which requires new semantic models (i.e., ontologies) for specific domains such as food. Once this is accomplished, trustworthy artificial intelligence (AI) based predictive models can be developed, providing advanced digital solutions for solving food system issues.

Official food control laboratories, such as EURLs/NRLs, have to face many emergencies and to constantly control food products to prevent damage to citizens caused by food contamination. In order to respond to the citizen needs, a coordination at the European level is necessary, and a focus on the metrological aspects of food-related measurements is needed. The accuracy of measurements should be improved and the traceability of measurement results to SI units should be established. Certified reference materials (CRMs) and rapid and calibrated screening methods can be developed to strengthen food analytics field.

2.2 Food safety and sustainability Policies and Strategies

Many European countries have set out their plans for current and future food safety and sustainability through published strategies, policies or legislative targets and smart specialization strategies (summarised in Table 1).

The European Commission recognizes research and innovation (R&I) as key drivers in accelerating the transition and achieving the objectives of the Farm to Fork Strategy, from primary production to consumption. R&I can help develop and test solutions, overcome barriers and uncover new market opportunities. In this spirit, the European Commission’s FOOD 2030 framework aims to find solutions to the challenges facing our food systems, such as obesity, malnutrition, hunger, climate change, scarce resources and high levels of waste through R&I. Prioritizing and integrating R&I on (1) nutrition (2) climate (3) circularity and (4) innovation is necessary for EU food systems to become future-proof – i.e. sustainable, resilient, responsible, competitive, diverse and inclusive.

Table 1 collects the range of food safety and sustainability strategies that were identified by the EMN Food members.

Table 1: Food safety and sustainability policies and strategies identified by the European Commission and EMN Food member country government’s

Country	Relevant policies and strategies
EU Member States	<p>World Economic Forum (2016). The global risks report 11th edition. Climate Change and Risks to Food Security. https://reports.weforum.org/global-risks-2016/climate-change-and-risks-to-food-security/</p> <p>European Commission (2019). The ‘Green Deal’ Communication. https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf</p> <p>European Commission (2015). An EU action plan for the Circular Economy. https://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_1&format=PDF</p> <p>European Commission (2020). The farm to fork strategy. https://ec.europa.eu/food/farm2fork_en</p> <p>European Commission (2020). Towards a sustainable food system. Moving from food as a commodity to food as more of a common good: independent expert report. https://op.europa.eu/en/web/eu-law-and-publications/publication-detail/</p>

	<p>/publication/ca8ffeda-99bb-11ea-aac4-01aa75ed71a1</p> <p>European Commission (2018). Food 2030: Future-proofing our food systems through research and innovation. https://op.europa.eu/en/publication-detail/-/publication/76d1b04c-aeafa-11e7-837e-01aa75ed71a1</p> <p>The ETP 'Food for Life' (2021). Implementation Action Plan http://etp.fooddrinkeurope.eu/news-and-publications/publications.html</p> <p>Farm to Fork strategy. https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en</p> <p>EFSA Strategy 2021-2027. https://www.efsa.europa.eu/sites/default/files/2021-07/efsa-strategy-2027.pdf</p> <p>Horizon Europe, Missions and Partnerships. https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/european-partnerships-horizon-europe_en</p> <p>UN Sustainable Development Goals. https://sdgs.un.org/goals</p>
Italy	<p>Development of precision agriculture and agriculture of the future.</p> <p>Systems and technologies for packaging, storage and traceability and safety of food production. https://www.agenziacoesione.gov.it/s3-smart-specialisation-strategy/strategia-nazionale-di-specializzazione-intelligente/</p> <p>Nutraceuticals, Nutrigenomics and Functional Foods</p> <p>Cl.uster A.grifood N.azionale (CL.A.N.) is a widely recognised multi-stakeholder association in the agri-food sector that brings together companies, trade associations, universities, research organisations, training bodies and local representatives operating in the agri-food sector. https://clusteragrifood.it/en/network/</p> <p>Smart specialization: https://www.s3.regione.lombardia.it/wps/wcm/connect/46779282-7753-4802-be85-837f90ace3ed/RIS3_Lombardy_Executive+Summary_20160411.pdf?MOD=AJPERES&CACHEID=ROOTWORKSPACE-46779282-7753-4802-be85-837f90ace3ed-nv01KGv</p> <p>https://www.regione.toscana.it/-/lancio-della-piattaforma-agrifood-della-smart-specialisation-strategy-a-firenze-il-6-e-7-dicembre</p> <p>https://www.regione.piemonte.it/web/temi/sviluppo/sistema-ricerca-innovazione/strategia-specializzazione-intelligente-s3-2021-2027</p> <p>https://s3platform.jrc.ec.europa.eu/region-page-test/-/regions/ITH3</p>
Germany	<p>Germany's National Sustainable Development Strategy (https://www.bundesregierung.de/resource/blob/998220/1941044/81190075aa2808adaeb73fa08b6e9bea/2021-07-09-kurzpapier-n-englisch-data.pdf?download=1) identifies sustainable agricultural and food systems as one of six area of transformation</p>

Greece	National Smart Specialization Strategy 2021-2027, Hellenic Republic, Ministry of Development and Investments
Slovenia	Slovenian Smart Specialization Strategy with the new priorities from 2012-2027: Optimization of agri-food supply chains including novel foods and products, quality raw materials in food Industry. https://www.gov.si/assets/ministrstva/MKRR/Slovenska-strategija-trajnostne-pametne-specializacije-S5-marec2022.pdf
Türkiye	<p>Towards Sustainable Food Systems National Pathway of Turkey. https://www.unfoodsystemshub.org/docs/unfoodsystemslibraries/national-pathways/turkey/2021-11-03-en-official-national-pathway-of-turkey-clean-31.10.2021-1-3.pdf?sfvrsn=a6aa2e6_1</p> <p>Toward sustainable food systems. https://www.tarimorman.gov.tr/ABDGM/Belgeler/Uluslararası%C4%B1%20Kurulu%C5%9Flar/NATIONAL%20PATHWAY%20OF%20TURKEY_29%20Kas%C4%B1m.pdf</p> <p>Türkiye’s National Strategy Document On Prevention, Reduction And Monitoring Of Food Loss And Waste And Its Action Plan. https://faolex.fao.org/docs/pdf/tur209489.pdf</p> <p>Ministry of agriculture and forestry 2019-2023 Strategic Plan. https://www.tarimorman.gov.tr/SGB/Belgeler/stratejikplan.pdf</p> <p>Ministry of Trade. https://ticaret.gov.tr/data/643ffd6a13b8767b208ca8e4/YMEP%202022%20Faaliyet%20Raporu.pdf</p>
Switzerland	<p>National Research Program “Healthy Eating and Sustainable Food Production” (NRP 69). NRP69 Synthesis brochure EN web.pdf (snf.ch)</p> <p>National Pathway for Food Systems Transformation in Support of the 2030 Agenda – Switzerland. https://summitdialogues.org/wp-content/uploads/2021/09/National-Pathway-for-Food-Systems-Transformation-in-Support-of-the-2030-Agenda-Switzerland_cleared-for-distribution.pdf</p> <p>Towards a Swiss Food Strategy for 2050. https://www.snf.ch/en/Qd6rU8cU5KsvCTEV/news/news-200625-press-release-towards-a-swiss-food-strategy-for-2050</p>

2.3 European Metrology Network for Food Safety and Sustainability

The need for this network arises from the fact that food safety is one of the major future challenges. For the NMIs/DIs this means that in the immediate future large demands from standardisation bodies and governments are expected, which require a coordinated action with stakeholders. In the framework of the established EMN, new research capabilities is built, participating at the competitive EU projects, in a coordinated way to avoid unnecessary duplications. The EMN Food intends to perform in terms of calibration and measurement capabilities relevant to food safety and

sustainability (i.e. quantification of food contaminants and characterization of traditional and innovative food packaging), at least comparable to those of other metrological communities outside Europe. As a result, metrology research developed within the network provide solutions for societal and agri-food challenges focusing on contributions to sustainable technologies and innovations in the food sectors.

EMN Food has to develop links between PT schemes, international comparisons at TC-MC and CCQM levels, CRMs and standardized measurement techniques and routine measurements at EURLs level, and consequently at stakeholder level. The EMN Food intends to design a large and integrated network to recognise the main and new issues about food technology related to production and control. The network works to put the knowledge together on the excellence and combined expertise of the different NMIs and DIs in the fields of metrology and of food technology. Their role is to bridge the gap between research and end-user communities and act as a central nucleus for measurement science activities, as well as to provide a platform for relevant stakeholders across Europe in order to easily identify relevant products, services and consultancy offered by EMN members. Further EMN Food addresses the four main gaps in the current knowledge: legislation and regulation, analysis, harmonisation and coordination, consumer and market confidence. The dialogue with EURLs that serve as centres of excellence in their respective areas of specialization will be established and improved. EMN Food seeks guidance and expertise from EURLs when encountering complex regulatory issues or when in need of technical assistance.

A network on food safety among the NMIs and DIs is addressed to conduct a census of the physical, chemical and biological measurement capabilities that are already applied, or that could be applied, in food field.

The EMPIR JNP 20NET02 Food-MetNet (2021-2024) supported the establishment of the EMN Food. The Euramet Board of Directors approved the formation of the EMN in September 2022. EMN Food member NMIs and DIs signed the MoU are presented in Table 2.

Table 2: EMN Food members and partners

No.	Logo	Abbreviation	Full name	Country
1		IMBiH	Institute of Metrology of Bosnia and Herzegovina	Bosnia and Herzegovina
2		IW	Institut za vode d.o.o. Bijeljina	Bosnia and Herzegovina
3		DFM	Danish Fundamental Metrology	Denmark
4		LNE	Laboratoire national de métrologie et d'essais	France
5		BAM	Bundesanstalt für Materialforschung und -prüfung	Germany
6		PTB	Physikalisch-Technische Bundesanstalt	Germany
7		EXHM/GSCL-EIM	National Laboratory of Chemical Metrology/General Chemical State Laboratory - Hellenic Institute of Metrology	Greece
8		INRiM	Istituto Nazionale di Ricerca Metrologica	Italy
9		GUM	Central Office of Measures/Główny Urząd Miar	Poland
10		MIRS/NIB/FITO	Metrology Institute of the RS/National Institute of Biology/Department of Biotechnology and Systems Biology	Slovenia
11		MIRS/IJS/F-2, O-2	Metrology Institute of the RS/Jožef Stefan Institute/Low and Medium Energy Physics	Slovenia

12		MIRS/ZRS Koper/LAB-IZO	Metrology Institute of the RS/ Science and Research Centre Koper/ Laboratory of the Institute for Oliveculture	Slovenia
13		METAS	Federal Institute of Metrology METAS	Switzerland
14		TUBITAK	Türkiye Bilimsel ve Teknolojik Arastirma Kurumu	Türkiye
15		LGC	LGC Ltd	United Kingdom
16		UT	University of Tartu	Estonia
17		EUROLAB	EUROLAB	
18		CVUA	Chemisches- und Veterinäruntersuchungsamt Stuttgart Sitz Fellbach	Germany

One of the objectives of the JNP 20NET02 is to develop a SRA and roadmaps to:

- address outstanding metrological requirements along the food supply chain taking into account the stakeholder needs;
- identify current and future challenges in food safety and sustainability;
- consider activities in existing infrastructure.

This document represents the realization of this objective.

2.4 Purpose of the document

This ‘Strategic Research Agenda’ (SRA) will be used by the EMN Food for formulating and sharing a harmonized and sustainable approach of the NMIs/DIs to contribute to the European measurement infrastructure and strategies. The document is intended to facilitate the food transition by highlighting where accelerated measurement activities are required. The document will be updated annually to reflect progress made regarding the measurement needs and challenges highlighted throughout.

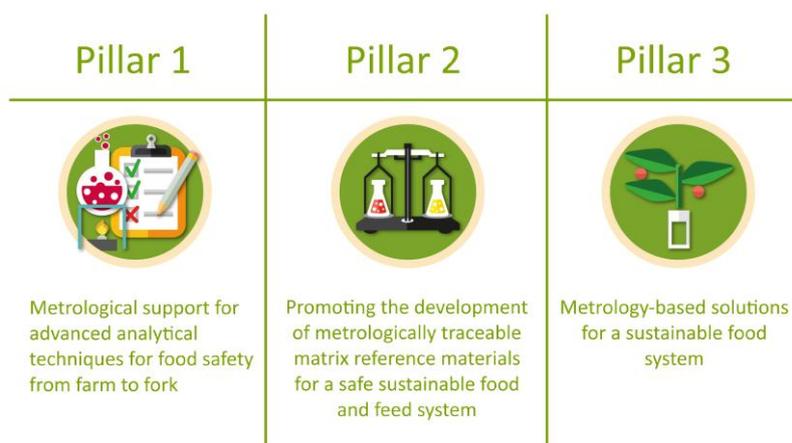
This document has been developed by EMN Food members and updated with input from relevant stakeholders and only focuses on topics considered under the theme of ‘food safety and sustainability’. It is important to point out that the metrology network infrastructure covers the food chain from “farm to fork” of relevant topics related to EU priorities, such as “food security”, “circular economy”, “nutrition and health” and “nanotechnology”.

Overall, the document serves as a holistic guide, offering valuable insights into the European landscape of food safety and sustainability. It provides a roadmap for the EMN Food to navigate current trends, policies, and measurement needs, fostering collaboration with global stakeholders and prioritizing research activities to address the most critical challenges in the field.

3 STRATEGIC FRAMEWORK: THREE METROLOGICAL PILLARS FOR ENSURING FOOD SAFETY AND SUSTAINABILITY

Guided by the perspective on a safe and sustainable food system, the work within the EMN Food is organized along three metrological pillars that define the backbone of the activities and the outputs of the consortium:

1. Metrological support to advanced analytical techniques for food safety from farm to fork.
2. Development of metrological traceable certified primary calibrators and matrix reference materials for a sustainable food and feed system.
3. Metrological solutions for a sustainable food system.



(Source: istockphoto.com/Macrovector and istockphoto.com/Vadim Sazhniev)

Figure 1: Strategic pillars of the EMN Food

This section provides an initial insight into how EMN Food navigates these pillars depicted below to achieve strategic excellence and promote sustainable growth.

3.1 Metrological support to advanced analytical techniques for food safety from farm to fork



(Source: istockphoto.com/AlexRaths)

To ensure a consistently high level of food safety across production and distribution, it is imperative to enhance and standardize analytical techniques in quantifying chemical contaminants. The network coordinates activities towards the development of reference methods for quantifying contaminants in food. Currently quantification of contaminants of emerging concerns or emerging

contaminants are the topics of paramount importance, since there are no defined maximum levels in the EU legislation, or the current maximum levels need to be revised. In this respect it is worth to mention perfluoroalkyl compounds (PFAS), mineral oil saturated/aromatic hydrocarbons (MOSH/MOAH), new generation of pesticides, pharmaceuticals, emerging mycotoxins, nano materials among others. The EMN Food extends its focus to encompass the detection and quantification of inorganic contaminants, recognizing their significance in ensuring comprehensive food safety measures.

Further it is also important to determine the source of toxic compounds in food, which is not always environmental pollution as generally believed and frequently found, but also adulteration of food products. EMN Food also deals with the methodology related to food authenticity including stable isotope approach, elemental composition and non-target food-omics.

Despite the existence of various analytical methods for determining biological and chemical safety in food, there is an urgent need for new strategies to enhance their reliability, sensitivity, selectivity, robustness and applicability. Moreover, it is mandatory to establish standard methods and to develop CRMs. False negatives, matrix effects and the need to improve detection limits are also of great concern when food contaminants are to be identified and quantified, considering the advancement in analytical methodologies. Rigorous evaluation of the measurement uncertainty is fundamental in respect to the amount of detected analyte and the food matrix. The validation of existing methods, involving additions or revisions to uncertainty and analytical parameters or application fields, is also a primary focus.

The EMN Food aims at coordinating efforts to deliver, in collaboration with relevant stakeholders and industries, innovative harmonized standards of international recognition for detecting and quantifying biological and chemical contaminants in food. This will represent groundwork for developing guidelines, new international standards, and reference methods to enforce legislation. The guidelines will cover various aspects in food supply chain, such as production, packaging and storage of foods and infant foods, where special attention is required due to the low body mass during child development.

The EMN Food will also provide training videos to facilitate the harmonised processing and interpretation of data from analytical measurements that are currently lacking in reproducibility (e.g. analysis of mineral oils).

3.2 Development of metrological traceable certified primary calibrators and matrix reference materials for a sustainable food and feed system



(Source: istockphoto.com/monstArr_)

In food analysis, reference materials (RMs) play an important role for implementing metrological principals and often serves as the only way to guarantee the quality of chemical and biological measurements by allowing to establish metrological traceability of the measurement results and

quantify measurement uncertainty. Reference materials (RMs) and CRMs are essential for various purposes, including method validation, performance verification, instrument calibration, measurement uncertainty evaluation, and quality control. It's important to note that an RM or CRM should be used in a specific step of an analytical procedure, necessitating a wide variety of RMs and CRMs to cover all steps in measurement procedures. Matrices covered by RMs commercially available include cereals, vegetables and vegetable oils, nuts, fruits, tea, fish, meat (including pork, beef, horse), milk products, various processed foods, beverages, drinking water and animal feed. Property values are given for trace and toxic elements, mycotoxins, polycyclic aromatic hydrocarbons (PAHs), nutritional components, proximates and stable isotope ratios. For a detailed collection of CRMs and RMs on the European market by May 2023 see Appendix 1.

The NMIs/DIs in the EURAMET region hold a total of 157 CMCs in various fields of food analysis and are actively extending the range by means of CCQM intercomparison participation. In this regard the EURAMET region is at eye level with each of the other holders of large number and range of CMCs (China Korea, Japan). For details on the CMCs held by each NMI or DI in the EURAMET region and worldwide by May 2023 see Appendix 1.

Nevertheless, despite an increase in the production of new RMs in recent years, there is still a lack of fit-for-purpose RMs especially for the food sector and there is a continuous need to develop new RMs with different matrix/analyte combinations to cover analytical requirements. Producing and evaluating them is the strategic focus of the EMN Food. Several of the NMIs/DIs that participate in the network have demonstrated capabilities of characterizing the purity of organic compounds and producing relevant calibrators that provide the missing traceability links for organic materials of intricate structure. Some members of the EMN Food have a tradition in proficiency testing and matrix reference materials (RMs) production with ISO 17034 certification (BAM, TUBITAK, LGC).

For example, TUBITAK UME has been organizing proficiency tests since 2000. The production and certification of RMs are carried out according to the ISO 17034 standard and ISO Guide 35 document, making it the first accredited reference material manufacturer in Türkiye (https://rm.ume.tubitak.gov.tr/urun_listesi_en.aspx). TUBITAK UME has primarily focused its food reference material projects on mycotoxins, toxic elemental content, food adulteration, and the authenticity of meat products. Since 2012, it has successfully completed the production of 12 CRMs and 18 RMs in the field of food analysis (https://rm.ume.tubitak.gov.tr/urun_grup_en.aspx?p=6gautd/aOdHzf2ckdjvqfw==).

Members in authenticity sector (JSI, LGC) developed together with Fondazione Edmund Mach (FEM) Indiana University (USA) and IAEA ten new food matrix RMs for hydrogen, carbon, nitrogen, oxygen, and sulphur stable isotope-ratio measurements to support food authenticity testing and food provenance verification. These new RMs, now USGS82 to USGS91, will enable users to normalize measurements of samples to isotope-delta scales. The RMs include (i) two honeys from Canada and tropical Vietnam, (ii) two flours from C3 (rice) and C4 (millet) plants, (iii) four vegetable oils from C3 (olive, peanut) and C4 (corn) plants, and (iv) two collagen powders from marine fish and terrestrial mammal origins [12].

Based on prior experience and a survey of the demand expressed by the stakeholders (JNP 20NET02: WP1, D1), members are planning the joint development of novel matrix RMs. Currently, members are developing the technical basis for reliable micro- and nanoplastic measurements in selected food matrices (PlasticTrace <https://plastictrace.eu/>) and will embark on investigating reliable measurement procedures for contaminants in food contact materials aiming at supporting recycling of food packaging (ScreenFood). Details will be clarified after the start of the JNP project ScreenFood (23IND13) in mid-2024.

Jožef Stefan Institute as a partner in international collaboration started the development of ten pure liquid volatile organic compounds (VOCs: acetonitrile, benzaldehyde, bis(methylthio)methane, dimethylsulfide, ethyl 2-methylbutyrate, furfural, 2-methyl-1-butanol, 1-octen-3-ol, (1S)-(-)- β -pinene, toluene) that will serve as H, O, C, N, S stable isotope RMs. Such VOCs are fragrant additives in food that can serve as diagnostic markers of origin and adulteration in food forensics. Additionally, we also include some non-food VOCs.

Further, there is also a lack of a European strategy on development of CRM in foods. Having standards to support the quality and provenance of food is of fundamental importance for trade, particularly for Europe, to support quality certification and to prevent fraud or counterfeit food products. Thus, at a regulatory level, obliging the use of CRM for analysis and certification, when they are available, would increase food safety and by combating fraud it would support the economy of food products originating from Europe.

The CRM production needs to be established at the metrological level to guarantee the worldwide acceptance of the results and the conformity of the ISO standards.

The EMN Food will support the organization of interlaboratory comparison aimed to the certification of reference materials, and the organization of PT schemes.

3.3 Metrological solutions for a sustainable food system



(Source: istockphoto.com/fcafotodigital)

With current global challenges such as climate change, resource depletion, and biodiversity loss, there is a growing demand to adopt sustainable practices in food production. Metrological solutions offer a systematic approach to address these challenges by providing precise measurement tools and methodologies to optimize resource utilization, minimize waste, and enhance the overall efficiency and sustainability of food production processes. The EMN Food will support activities in several key areas:

- **Development of metrological and analytical solutions for recycled food packaging:** The EMN aims to contribute to the development of new metrological approaches in the food sector by promoting sustainable food packaging solutions such as natural and biopolymer-based polymers, active and intelligent packaging materials, and the study of the effectiveness and safety of sustainable packaging materials. This will involve collaboration with industrial partners in the food and food packaging production sectors and is a part of the new accepted JRP project ScreenFood.
- **Reuse of food wastes:** Waste of food, phenomena nowadays mostly observed in industrial nations, is frequently results of throwaway culture, where more food is purchased than consumed. It is known that non-edible portions of agri-food products can contain high amounts of phytonutrients and valuable bioactive compounds that, if extracted, can have an immense added value in a wide range of applications as food additives, nutraceuticals, therapeutics, cosmetics.

Food by-products and wastes can contain chemical contaminants or potential pathogens that may endanger consumers' health. EMN Food's efforts are directed towards valorisation and reuse of by-products to assure their quality and safety.

- **Characterization of novel foods:** This aspect will involve assessing the properties and safety of novel foods. Some examples are algae, seaweed and krill, insects, and terrestrial non-chordate phyla. The EMN Food understands alternative protein sources as additional protein source for growing population, improvement of food security and building more diverse and resilient food system. The Regulatory authorities universally acknowledge the methodological challenges inherent in assessing the safety of novel foods and ingredients, often characterized by their complexity and sometimes high levels of dietary incorporation. These challenges will be also the topic of EMN Food in order to provide appropriate methods and approaches to characterize the novel food and determine their safety.
- **Metrology for novel methods:** An increasing trend in the food industry to use process analytical technologies (PAT) in support of process automatization has been noticed. Efficient production processes and quality control should benefit from point-of-need screening based on novel methods of analysis. This will largely abandon the concept of analysing specific elements or compounds (elements, vitamins, contaminants, etc.) directly but rely on indirect, often spectroscopic procedures. Trace contaminants, one of the most important aspects of this EMN, however, will not be accessible that way. Also, matrix CRMs and proficiency testing in the current sense are not applicable in this context. Consequently, not only the principal fitness for purpose of such PAT but also their accuracy, the comparability among different approaches and different providers of respective services are challenges for stakeholders in coming years. Current concepts of traceability may not easily be transferred and might require adjustment. EMN Food intends to monitor activities in this field in close contact with METROFOOD-RI and assess potential contributions.
- **Digitalization:** Digital transformation is transforming the way the entire food sector works, and will therefore be an indispensable element of education, research and innovation in the future. The members intend to support digitization in the fields covered by the network. This includes: digital RM certificates in connection with metrological services, introducing big data and data collection in the food supply chain, new developments in automatization and data exchange, machine learning and artificial intelligence (AI).

Through these initiatives, the EMN Food aims to align with the EU "One Health action plan" and support industry efforts to reduce the occurrence of undesired contaminants in food, foster consumer trust, and promote the adoption of sustainable practices within the food sector.

4 MEASUREMENT NEEDS

Addressing the measurement needs in the food supply chain for safety and sustainability presents numerous challenges, related to economic, social and environmental aspects:



Figure 2: Challenges addressed by the EMN Food.

These include the complexity of measuring multiple parameters simultaneously, the variability of natural and agricultural systems, and the need for harmonized measurement standards and methodologies across diverse geographic regions and regulatory frameworks.

The measurement needs have been evaluated at different levels:

- The measurement needs related to EU and national legislation and strategies (see Table 1).
- The measurement needs within CCQM Working groups. The food related items currently conducted or planned/discussed by CCQM are collected by working groups including Isotope Ratio Working Group (IRWG), Nucleic acid Analysis Working Group (NAWG), Inorganic Analysis Working Group (IAWG), Organic Analysis Working Group (OAWG), Protein Analysis Working Group (PAWG), Surface Analysis Working Group (SAWG) and the input of EMN members is indicated (see Appendix 2). Members of the EMN intend to coordinate their input to WG/BIPM in order to influence future directions such that the interests of countries in the EURAMET region are properly considered. In support of this quest, the EMN Food will guarantee a representative within Food Analysis Working Group – FAWG.
- Link and dialogue with existing infrastructure (METROFOOD-RI and EUROLAB).
- Stakeholder measurement needs obtained by survey (presented in Table 3).
- Further items that have been identified by the EMN Food members as currently being relevant in connection with metrological services required by stakeholders in official food control and industry (presented in Table 3).

Table 3: Measurement needs identified at different levels:

Measurement needs and challenges	Identified by		EURAMET project
	EMN partners	Stakeholders	
Lack of legislation, validated methods, RMs , and interlaboratory comparisons to underpin PFAS in food. Definition of categories of PFAS and to establish persistency and toxicity. In the longer term, a greater understanding on the universe of PFAS is needed.	Yes	Yes	ScreenFood
Lack of legislation, harmonized methods and RM for MOSH/MOAH . The reliability of MOAH quantifications by harmonising SOPs for the elimination of interferences and assessing chromatograms for food matrices. RMs for food.	Yes	Yes	ScreenFood
Lack of RMs for organic (PFAS, MOSH/MOAH, new generation of pesticides, CEC, PAHs, mycotoxins) and inorganic contaminants, stable isotopes, mikro-, nano-plastics, nano particles, GMOs, allergens, bacteria nans virusis in food matrices. Need for organization of interlaboratory comparison.	Yes	Yes	Partially in ScreenFood
A comprehensive and robust metrological framework is needed to characterise and quantify microplastic (>1 µm <1 mm) and nanoplastics (<1 µm) in food and to better understand transport and bioaccumulation. Harmonised measurand definition, CRMs, harmonised sampling protocols, and inter-laboratory comparisons are needed.	Yes	Yes	PlasticTrace
Harmonized and adoptive methods for elemental analysis of toxic elements and its speciation (As, Hg, Cr, Se) . RMs not available at low concentrations. Traceability in the field of traditional elements (Cd, As, Pb) with respect to the lowered maximum limits. Traceability for emerging toxic elements (Al, Sb, Ba,...)	Yes	Yes	Partially in ScreenFood
New methods need to be developed for the detection/determination of veterinary drugs residues.		Yes	n/a
Determination of vitamins A, D, E and B in feed. There is a very limited range of CRMs and proficiency testing schemes available involving analytes such as vitamins in feed and feed materials. The determination of vitamins in feed can be problematic and would benefit from the development and standardisation of improved methods of analysis.		Yes	n/a
Traceability for furan/alkylated furans and MCPDs and GEs has to be established.		Yes	n/a
Cannabidiol (CBD) in food and feed. It appears to be an increasing use of CBD in pet food and animal feed. Development of methods for the determination of CBD in		Yes	n/a

feed matrices would be of use.			
Stable isotopes of light (H, C, N, O, S) and heavier (Sr, Pb, B) elements for authenticity and traceability – harmonized methods, validation. Novel methodology for SI traceable isotope standards and characterisation practices for reference and isotopically-enriched materials need to be developed.	Yes		n/a
Non-targeted analysis in food include screening techniques to monitor safety and foodomic techniques to determine authenticity. Multi-analyte reference materials are needed to ensure traceability.	Yes		n/a
Effective GMO analysis requires access to three things: knowledge of the DNA sequence alteration, a validated method, and a CRMs (i.e. quantitatively at low level percentage for authorized GMO; and qualitatively/identity for non-authorized GMO)	Yes	Yes	n/a

4.1 Link and dialogue with existing infrastructures

The measurement needs of METROFOOD-RI infrastructure for food characterization is related to different analytical approaches for assessing raw materials, process intermediates, and final products from both plant and animal origins. Additionally, there's a focus on evaluating food contact materials, by-products, and side streams for quality, safety and authenticity. These measurements encompass a range of parameters, including markers of origin such as botanical, zoological, and geographic indicators, as well as emerging contaminants like micro- and nano-plastics. Furthermore, there's growing interest in employing structural biology techniques to elucidate food properties. EMN Food can address these needs through:

- certification campaigns for RMs;
- organization of interlaboratory comparisons;
- method standardisation;
- development of standard operating procedures for selected matrices.

4.2 Stakeholder input on measurement needs

The priority areas and stakeholder measurement needs in the field of food safety and sustainability were identified throughout comprehensive stakeholder survey as a part of the WP1 of JNP 20NET02. The survey was circulated to approximately 100 stakeholders, with a total of 40 responses. The challenges in the development of new analytical methods, in the provision of interlaboratory comparisons and in supplying provision of new calibrants and certified reference materials to improve standardisation were identified and included in SRA. The results collected by mid 2023 are reported in Table 3.

There was a good distribution of responses from across Europe and we received 36 responses from our targeted stakeholder groups, which gave us an understanding of the priorities from EURLs, NRLs and Government. However, a limited representation of Industry and Academic community was observed that need to be improved in the future.

Stakeholders were asked to identify up to five areas (out of 17) of interest in metrology related to food safety and/or sustainability that had been determined by the EMN. The results are presented in Figure 3. Food contaminants (27%) and food testing (21%) resulted to be the most relevant areas to be addressed followed by finished product (18%), food packaging (17%) and food authenticity (16%).

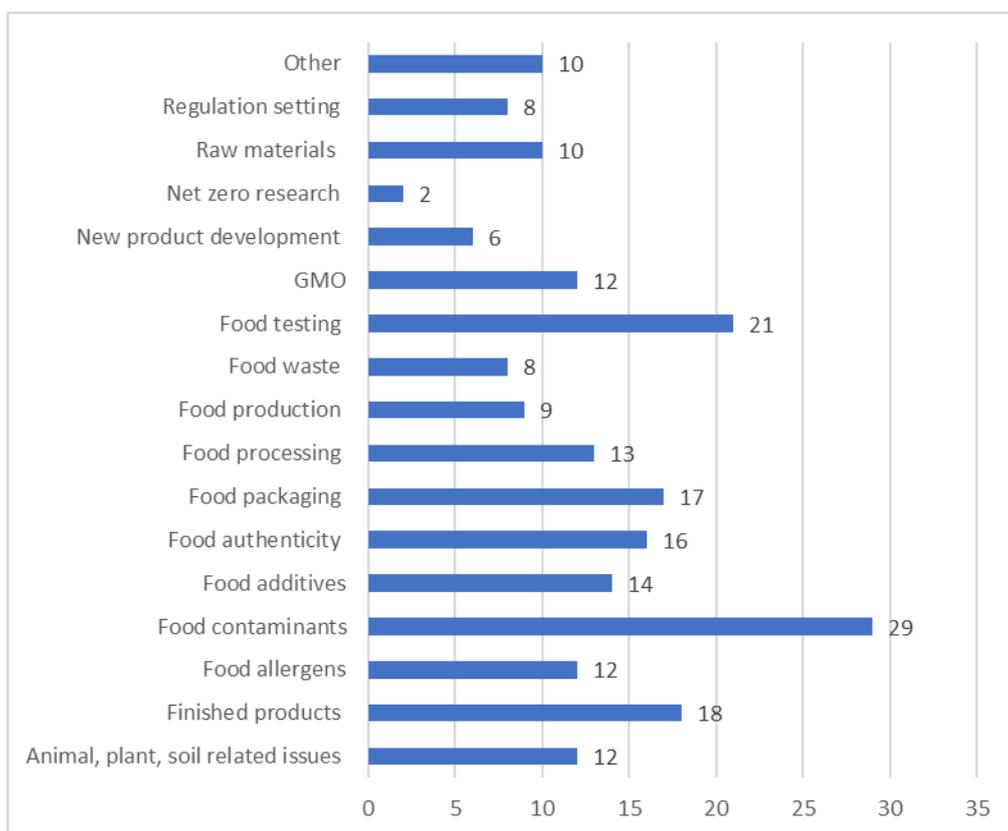


Figure 3: Areas of interest in metrology related to food safety and/or sustainability. N.B. Respondents could select up to five areas of interest.

The development of analytical methods is the priority area for measurement support in analysis of new or emerging areas, followed by Interlaboratory comparison studies, which can then be a route for establishing metrological traceability. Less important is access to equipment or measurement services. There were several topics that came up a few times in the additional details section, including olive oil authenticity, determination of vitamins in feed and new methods for the detection of veterinary drug residues.

The priority area for measurement support for analytical tools is for provision of CRMs (34%). Calibration standards (27%) and data repositories for reference purposes (14%) were less important. The respondents want the RMs focused on their specific area of interest rather than generic ones. The network will have to focus its efforts and consider in which areas of interest they may have the greatest impact. The help in this direction could be also the improvement of survey question related to RM. The survey will be regularly advertised through EMN Food webpage, and web tools (Linkedin) and in the occasion of dissemination activities, in order to gather updated inputs by relevant stakeholders. A critical analysis of the results of the survey will be carried out annually and discussed during the GA. This will constitute the basis for planning activities in the coming year.

5 IMPLEMENTATION ROADMAP & PRIORITISATION

This section outlines the strategic plan for implementing the key initiatives of EMN Food, establishing a clear pathway to achieve our goals. It prioritizes actions based on their potential impact and feasibility, ensuring that resources are effectively allocated to maximize benefits.

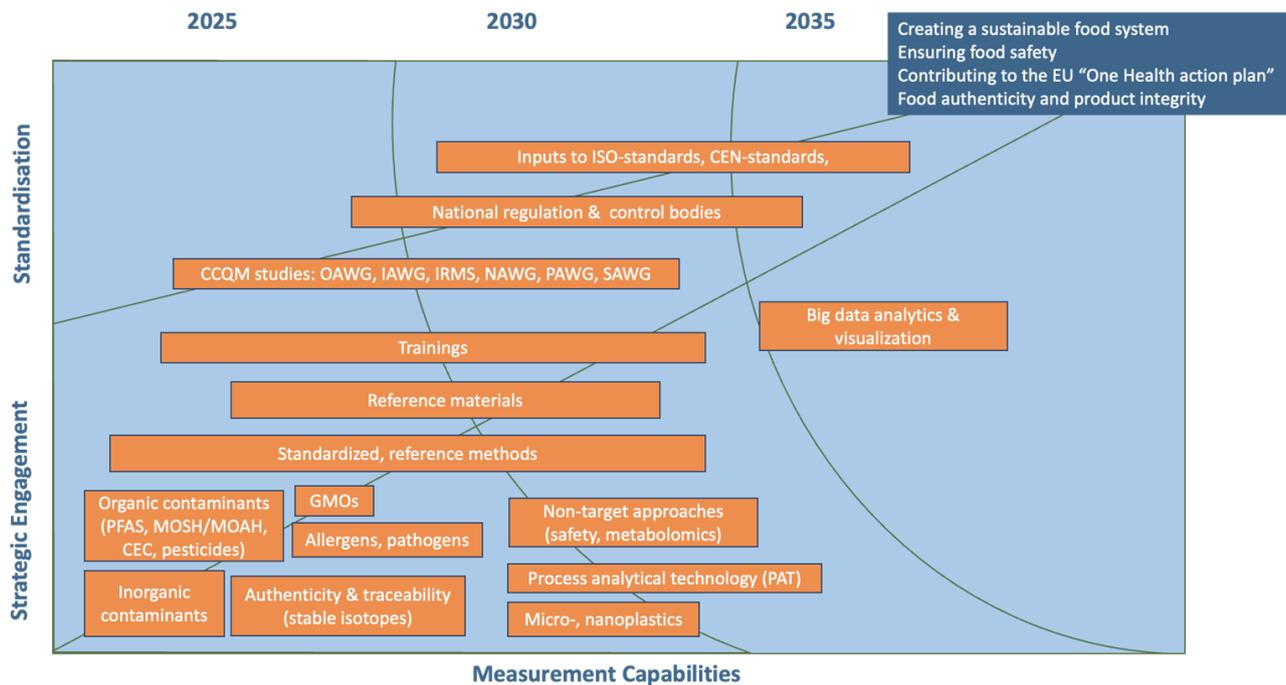


Figure 4: Implementation roadmap: Support for key EU priorities (creating sustainable food system, ensuring food safety, contributing to the EU “One Health action plan” and safeguarding food authenticity and product integrity).

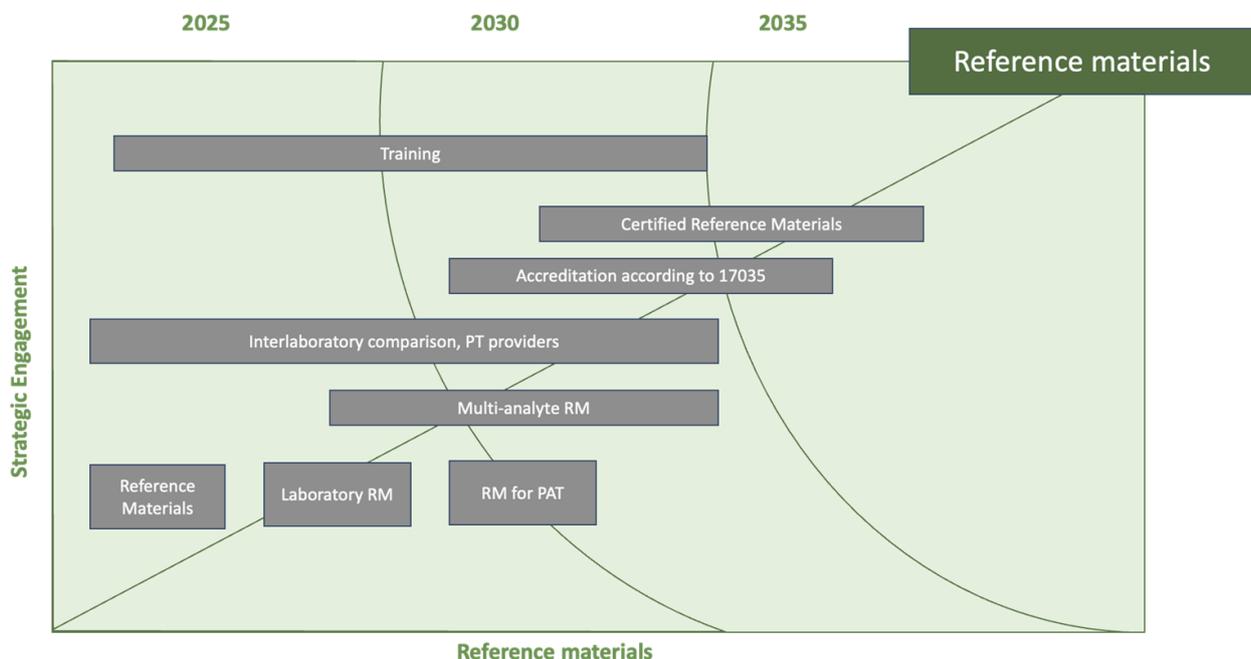


Figure 5: Implementation roadmap: Reference materials

The roadmap is designed to align with European needs: to create a sustainable food system, ensure food safety, contribute to the EU's "One Health action plan", safeguarding food authenticity and product integrity, assure animal welfare and plant health and support industry efforts. By focusing on the development and application of CRMs and promoting sustainable practices, this plan aims to

enhance food safety, reduce contaminants, and build consumer trust. Each step is carefully considered to foster collaboration among metrology institutes, regulatory bodies, and stakeholders, driving progress in the food sector through coordinated and well-prioritized efforts.

Additionally, the two developed roadmaps serve as benchmarks for measuring future progress.

The real advantage is in the coordination and realising the best synergy of all these activities. The first attempt has been provided within ScreenFood JNP project that will start in June 2024. The schematic presentation of the project connecting all three pillars is presented in Figure 5.

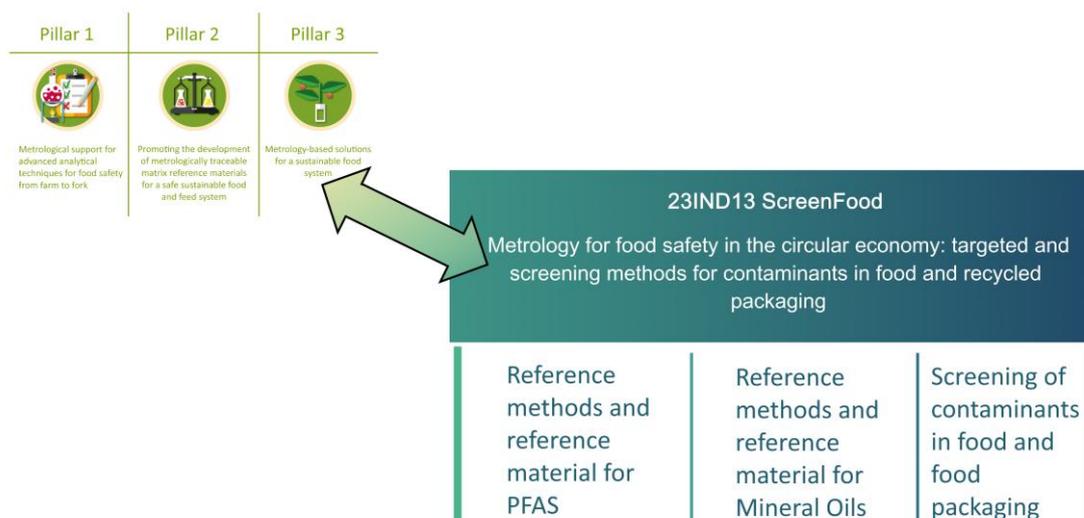


Figure 6: Schematic presentation of ScreenFood JNP connecting all three pillars.

6 CONCLUSIONS

Food safety and sustainability have never been more complex than today and will become increasingly challenging in the future. Metrological solutions offer a systematic approach to address these challenges by providing precise measurement tools and methodologies to optimize resource utilization, minimize waste, and enhance the overall efficiency and sustainability of food production processes.

The EMN Food Strategic Research Agenda focuses on ensuring food safety and sustainability through three key pillars: supporting advanced analytical techniques, developing traceable certified calibrators and reference materials, and providing metrological solutions for sustainable food systems. The implementation roadmap aligns with EU priorities, aiming to create a sustainable food system, ensure food safety, and build consumer trust through coordinated efforts and collaboration among stakeholders.

Overall, the document serves as a holistic guide, offering valuable insights into the European landscape of food safety and sustainability, addressing complex challenges strategically to maximize the impact of future research programs.

7 REFERENCES

1. Strategic Research and Innovation Agenda of the ETP 'Food for Life', Food for tomorrow's consumer, July 2016
2. World Health Organization (WHO) (2014) Food safety fact sheet. Available at <https://www.who.int/news-room/fact-sheets/detail/food-safety>
3. Sorbo, A., Zoani, C., Passeri, D. (2023) Food Quality and Safety: Advances in Analytical Methods and Applications. Separations 10315. <https://doi.org/10.3390/separations10050315>
4. Johnson, R. (2014) Food Fraud and “Economically Motivated Adulteration” of Food and Food Ingredients Congressional Research Service Report 7-5700
5. Spink, J. (2009) Food Profiteering and the counterfeit product threat In Feeding our Hungry Planet, Michigan State University. Symposium presentation
6. World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP/248 2017.
7. FAO (2016) Food loss and food waste [Internet]. Food and Agriculture Organization of the United Nations; [cited 2016. Jan 24]. Available from: <http://www.fao.org/food-loss-and-food-waste/en/>
8. European Commission, Directorate-General for Research and Innovation, Bizzo, G., Fabbri, K., Gajdzinska, M. et al., Food 2030 – Pathways for action 2.0 – R&I policy as a driver for sustainable, healthy, climate resilient and inclusive food systems, Publications Office of the European Union, 2023, <https://data.europa.eu/doi/10.2777/365011>
9. van den Berg F, Lyndgaard CB, Sørensen KM, Engelsen SB. (2013) Process analytical technology in the food industry. Trends in Food Science and Technology 231, 27–35. <https://doi.org/10.1016/j.tifs.2012.04.007>.
10. Hitzmann B, Hauselmann R, Niemoeller A, Sangi D, Traenkle J, Glassey J. (2015) Process analytical technologies in food industry – challenges and benefits: a status report and recommendations. Biotechnology Journal 10, 1095–1100. <https://doi.org/10.1002/biot.201400773>.
11. Mattarozzi, M., Laski, E., Bertucci, A., Giannetto, M., Bianchi, F., Zoani, C., Careri, M. (2023) Metrological traceability in process analytical technologies and point-of-need technologies for food safety and quality control: not a straightforward issue. Analytical and Bioanalytical Chemistry 415, 119-135, <https://doi.org/10.1007/s00216-022-04398-5>
12. Schimmelmann, A., Potočník, D., Ogrinc, N., et al. (2020). Food matrix reference materials for hydrogen, carbon, nitrogen, oxygen, and sulfur stable isotope-ratio measurements. Journal of Agricultural and Food Chemistry 68/39, 10852-10864. DOI: 10.1021/acs.jafc.0c02610

8 APPENDIX 1

Appendix 1 includes the collection of Calibration and Measurement Capabilities (CMCs), the collection of food related Matrix Reference Materials and a list of measurement capabilities available in the EMN.

CMCs held by EMN members

The BIPM database (<https://www.bipm.org/kcdb/cmc/quick-search>) was used to collect the information on calibration and measurement capabilities (CMCs) of the EMN partners. A simple list as suggested by the workbook, however, would not be appropriate to accommodate the complex information available for each respective CMC. This detailed information is crucial for the assessment of a given CMC in the potential context of providing metrological services such as measurement trueness and precision, covered range and traceability. Therefore, an Excel pivot table was prepared that allows easy retrieval of the contained information on food related CMCs according to covered matrices, analytes, concentration ranges as well as the country and NMI/DI of origin. In addition to the CMCS held be NMIs/DIs in the EURAMET region, all other food related CMCs were included. For details see the register “read me” therein. It should be noted that this compilation mirrors the status in May 2023. A graphical overview on the currently existing CMCs in the food sector is given in Fig. A1. It displays the countries and world regions with their respective number of food related CMCs held.

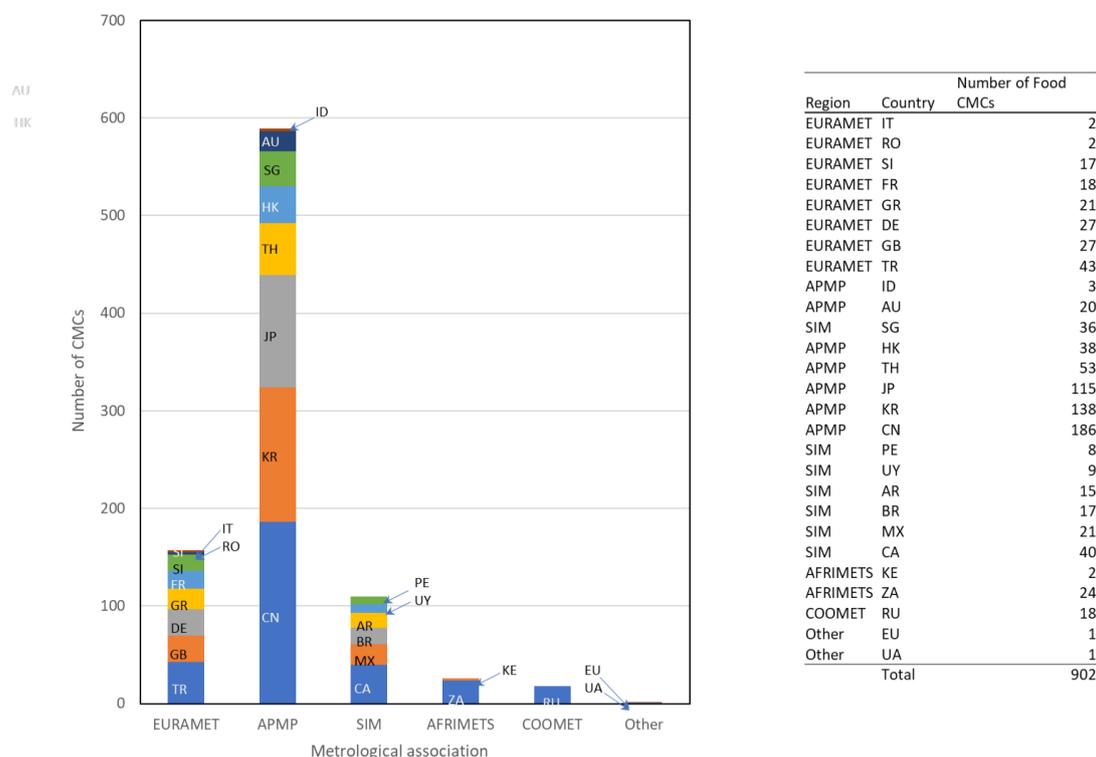


Fig. A1: Calibration and Measurement Capabilities (CMCs) held by countries in different world regions

Food-Related Matrix Reference Materials

A simple list of CRMs as required does not appear to be helpful for the objectives of the JNP/EMN such as evaluating stakeholder needs and assessing future needs regarding the development of reference materials. In addition, the term “CRM” has been defined by ISO TC 334 (formerly ISO REMCO) but there has never been an independent assessment of the commercialized reference materials regarding the validity of the label “certified” and it is certainly beyond the scope and capability of this JNP to embark on such a venture. On the other hand, non-certified RMs may often be appropriate for a specific purpose and certainly are considered as such by many users especially if there are no alternatives available. Therefore, instead of a simple list, an Excel document was prepared that contains the more than 860 food-related matrix RMs and CRMs available on the

European market. The information was retrieved from openly available sources such as resellers and original providers of matrix reference materials and also provided by members of the EMN. Separate registers were established for the main matrix groups:

- Cereals
- Genetically modified organisms
- Fruit, plant matrix, oils
- Milk and milk products
- fish, fish products, mussels
- Processed food, spices
- Juice, alcoholic beverages
- Additives and allergens
- Authenticity, stable isotopes
- Feed
- Water and drinking water
- Packaging

This categorization is considered the best compromise between a rapid overview of available materials and the access to (a) specific material(s) via certain characteristics such as material acronym, matrix, measurand(s) or provider. In each register, the respective acronym, the matrix, the measurand(s) and the amount of material per unit are listed along with the provider and country of origin. The certification status of each material was tentatively assessed. Fig. A2 provides a graphical overview of the (C)RMs in the respective categories available on the European market. It should be noted that this compilation mirrors the status in May 2023.

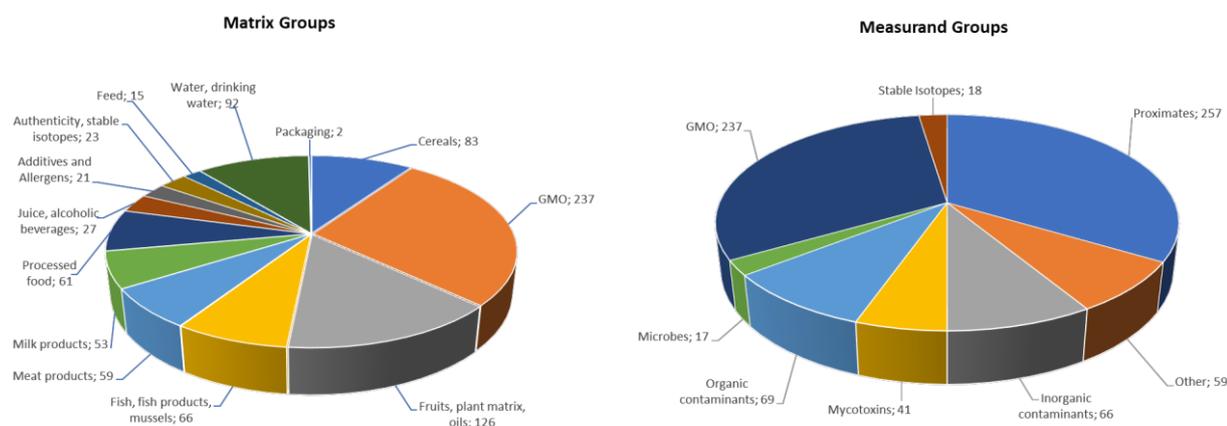


Fig. A2: Matrix Reference Materials available in Europe categorized by matrix and measurand groups

Measurement Capabilities

The required measurement capabilities of the EMN members are collected in Table A1. It includes those analytical methods that the EMN members provided on request by May 2023. It should be noted that this list includes exclusively such methods that might be employed by the respective members for the EMN objectives such as reference materials development where appropriate and is considered an EMN internal information. This list is not identical with or part of the service platform that will be part of the future EMN website. In addition to the listed analytical procedures, several EMN members have facilities to prepare, store, and market (matrix) reference materials at their disposal.

Table A1: Measurement capabilities of EMN members (for acronyms, see Table A2)

Member	Gas chromatography	Liquid chromatography	Elemental/inorganic analysis	Spectroscopy	PCR, ELISA	Other
INRIM	GC-EA IRMS	UPLC-MS	ICP-MS	NMR, qNMR, Raman, TERS, IR spectroscopy		AFM, STM
LGC	GC-ICP-MS	LC-ICP-MS, FFF-ICP-MS	LA-ICP-MS, MC-ICP-MS, Q-IMS-ToF-MS, QQQ, Qtrap, Orbitrap	qNMR	dPCR, qPCR, NGS, ELISA	MSD-Sector Imaging, Confocal microscope (laser dissection), Flow cytometry
JSI	GC-MS, GC-IT-MS, GC-C-IRMS, GC-ICP-MS	LC-ICP-MS, LC-MS/MS, UPLC-qToF-MS/MS	(TQ-)ICP-MS, LA-ICP-MS, SP-ICP-MS, HG AFS, EA-IRMS, DI-IRMS, MC-ICP-MS	Raman, HR-gamma ray spectrometry		LSC, Py-IRMS
BAM	GC-FID, GC-ECD, GC-MS (with HS and SPME); GC-MS/MS; TDU-GC-MS; GCxGC-TOF-MS(/MS)	HPLC-DAD/FLD, HPLC-GC-FID, UPLC-qToF-MS, UPLC-MS/MS	ICP-MS, ICP-OES, CA AFS	qNMR	dPCR, qPCR, NGS, ELISA	
METAS	GC-MS/MS, GCxGC-TOF-MS	HPLC-GC-MS	SF-ICP-MS, TQ-ICP-MS, ICP-OES, LA-ICP-MS, Direct Mercury Analyzer		dPCR, qPCR	
TUBITAK	GC-FID, GC-ECD, GC-MS/MS, GC-MS	HR-LC-MS, Q Exactive Orbitrap MS, LC-MS/MS, UPLC, HPLC-DAD	EA-GC-HPLC-IR-MS, HR-ICP-MS, HPLC-ICP-MS, ICP-MS/MS, ICP-OES, AAS, IC	qNMR		
EXHM	GC-IT-MS	HPLC-qToF-MS, HPLC-MS/MS, HPLC-DAD/CAD/RI/FLD		qNMR		
GUM			ICP-OES, ICP-MS, IC, IC-ICP-MS			
LNE	GC/MS, GC-MS/MS, GC-FID, HS-GC-MS, GC-TOF-MS	HPLC-DAD/FLD	ICP-OES, ICP-MS, IC	RMN, UV-VIS, XRF, XRD		
NIB					PCR, qPCR, dPCR, sequencing, LAMP	Microscopy, MALDI-ToF
ZRS-KP	GC-MS/MS, GC-FID	HPLC-DAD/FLD/RID, LC-MS/MS (TQ)		UV-VIS, NIR		
IW	HS-GC-FID, HS-GC-ECD, GC-MS/MS	HPLC-MS/MS, HPLC-PDA/FLD	ICP-OES, AAS-GFA, flame-AAS			

Table A2: Abbreviations of Measurement Procedures listed in Table A1

Abbreviation	Full description
AAS-GFA	Graphite furnace-Atomic Absorption Spectrometry
ATM	Atomic Force Microscopy
CAD	Charged Aerosol Detection
C-IRMS	Carbon Isotope Ratio MS
CV AFS	Cold Vapour AFS
DI-IRMS	Dual Inlet IRMS
dPCR	Digital PCR
ECD	Electron Capture Detection
ELISA	Enzyme-linked Immunosorbent Assay
FFF	Field Flow Fractionation
FID	Flame Ionisation Detection
GC	Gas Chromatography
HG AFS	Hydrid Generation Atomic Flourescence
HPLC	High Performance Liquid Chromatography
HS	Head Space
IC	Ion Chromatography
ICP	Inductively Coupled Plasma
IMS	Iom Mobility Spretrometry
IRMS	Isotope Ratio MS
IT	Ion Trap
LA	Laser Ablation
LAMP	Loop-mediated Isothermal Amplification
LSC	liquid Scintillation Counting
MALDI	Matrix Assisted Laser Desorption/ionisation
MC	Multicollector
MS	Mass Spectrometry
NGS	
PCR	Polymerase Chain Reaction
PDA	Photodiode Array Detector
Py-IRMS	Pyrolysis IRMS
qNMR	Quantitative Nuclear Magentic Resonance
qPCR	Real-time PCR
Q	Quadrupole
QQQ	See TQ
RID	Refractive Index Detector
RMN	Food Analyser (NMR)
SF	Sector Field
SP	Single Particle
SPME	Solid Phase Micro Extraction
STM	Scanning Tunneling Microscopy
TERS	Tip Enhanced RAMAN Spectroscopy
TOF	Time of Flight
TQ	Triple quad
UPLC	Ultra Performance Liquid Chromatograpy
XRD	X-ray Diffraction
XRF	X-ray Flourescence

9 APPENDIX 2

This appendix includes measurement needs within BIPM Working Groups.

IRWG: Isotope Ratio Working Group	
Challenges:	<p>There are four main challenges associated with measurement of isotope ratio data for food testing such as authentication:</p> <p>1 – Reference materials</p> <p>Many of the available isotope delta reference materials for the light elements do not comply with current requirements such as certification in accordance with ISO Guide 34 or use of accredited measurement laboratories for provision of data. Questions also remain regarding the measurement uncertainty associated with reference material isotope delta values, particularly those characterised by inter-laboratory comparison. At present no major NMI has a programme in this area. NIST have a limited number of existing products but no longer have an active programme of IRMS standards. Only a few other certified reference materials for isotope delta have been produced by other metrology institutes. Unless positive action is taken to change this situation, we are faced with a steadily worsening situation.</p> <p>2 – Standard methods and databases</p> <p>Many of applications of isotope ratio measurements for food authentication rely on differences in isotope delta values between foodstuffs with different origin or history. As a result, databases of isotope delta values of known-origin, authentic foodstuffs must be developed and populated. Ongoing maintenance of such databases requires standardized methods of analysis that provide isotope delta values that are repeatable within laboratories and reproducible among laboratories.</p> <p>For some elements, particularly hydrogen, this is very challenging due to the difficulties in removing all water prior to analysis. Any remaining water will have a hydrogen isotopic composition that varies between laboratories and over time and bias measurement results. In addition, the presence of labile protons in sample materials further complicates analysis as these protons will reflect the hydrogen isotopic composition of the water the sample was last exposed to (usually moisture in laboratory air) and must therefore be accounted for to allow results to be reproducible between laboratories.</p> <p>3 – Sample preparation and correction for mass bias</p> <p>For isotope ratio measurements beyond H, C, N, O and S that are also used for food analysis (e.g. B, Sr, Pb, etc.) the measurements of isotopic composition by MC-ICP-MS requires extraction of the element from the sample matrix without fractionation of isotopic composition; while instrument measurements must be corrected for mass bias. Both are challenging due to the limited number of reference materials, particularly matrix reference materials for foods.</p> <p>4 - SI-traceability</p> <p>Isotope delta for H, C, N, O and S is reported relative to international standards that may be “virtual” or exhausted and have no SI traceability. Traceability of reference materials to those standards is jeopardised by poor metrology surrounding characterisation by interlaboratory comparison. Availability of MC ICP-MS and optical instruments has stimulated “absolute”</p>

	<p>and relative stable isotope ratio measurements. Some applications require determinations with very low uncertainty for minor isotopic constituents. This is especially difficult where the main isotope has an abundance > 99%. Novel methodology for SI traceable isotope standards and characterisation practices for reference and isotopically-enriched materials need to be developed.</p>
Relation to food analysis	<p>Among the exploitable techniques, stable isotope-ratio signatures ($\delta^2\text{H}$, $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, $\delta^{18}\text{O}$, and $\delta^{34}\text{S}$) are currently leading the way in food authenticity and traceability in three main areas of application, namely (i) detection of adulteration; (ii) verification of geographical origin; and (iii) identification of mode of production, i.e., organic vs. conventional farming systems.</p> <p>Other isotope systems such as B, Sr and Pb can also be used in these three areas. Combinations of multiple isotopic analyses and other analytical techniques such as trace element analysis can be powerful tools to discriminate between authentic and non-authentic foods.</p>
NMIs/Dis active	INRIM, LGC, JSI, BAM, PTB, TUBITAK UME
Key-stakeholders	The Forensic Isotope Ratio Mass Spectrometry (FIRMS) Network, IAEA, JRC
Overview	<p>Given the ease with which isotopic fractionation can occur during sample preparation and the measurement itself, it is essential to have reliable, stable reference materials to afford traceability. Yet we have a situation where the international infrastructure lacks SI traceability and is largely based on artefacts or virtual standards given that the original materials either no longer exist, are in very short supply, or have been later found to be unsuitable due to instability or previously undiscovered heterogeneity. Application of recent improvements in absolute isotope ratio measurements by IRMS as well as techniques orthogonal to IRMS affords the possibility of linking the isotope delta scales to the SI.</p> <p>Many of the available isotope delta reference materials for the light elements do not comply with current requirements such as certification in accordance with ISO Guide 34 or use of accredited measurement laboratories for provision of data. Questions also remain regarding the measurement uncertainty associated with reference material isotope delta values, particularly those characterised by inter-laboratory comparison. At present no major NMI has a programme in this area. NIST have a limited number of existing products but no longer have an active programme of IRMS standards. Only a few other certified reference materials for isotope delta have been produced by other metrology institutes. Unless positive action is taken to change this situation, we are faced with a steadily worsening situation.</p>
Outlook beyond 2033	<p>Isotope delta for H, C, N, O and S is reported relative to international standards that have no SI traceability. Traceability of reference materials to those standards is jeopardised by poor metrology surrounding characterisation by interlaboratory comparison. Availability of MC ICP-MS and optical instruments has stimulated “absolute” and relative stable isotope ratio measurements. Novel methodology for SI-traceable isotope standards and characterisation practices for reference and isotopically-enriched materials need to be developed.</p> <p>Development and metrological validation of methods for SI-traceable “absolute” ratio measurements with very low uncertainty of the commonly</p>

	<p>used isotope pairs of the light elements (H, C, N, O and S). Where possible, independent measurement techniques will be applied to re-determination of the absolute isotope ratio of the international measurement standards (i.e. the “delta zero” materials).</p>
<p>On-going plan</p>	<p>Development and metrological validation of approaches to combine data from inter-laboratory exercises during certification of isotope delta reference materials that recognise the covariances introduced through use of the limited suite of existing reference materials within the complex calibration network used to afford traceability to the international measurement standards.</p> <p>Development of a standard method for hydrogen isotope delta in food materials that produces consistent results within measurement uncertainty between laboratories. This should include accounting for labile protons as well as a reproducible drying method.</p> <p>Development and metrological validation of MC ICP-MS methods for SI-traceable absolute isotope ratio measurements with very low uncertainty of isotopically-enriched materials used in preparation of gravimetric mixtures, in isotope dilution mass spectrometry and in materials science applications. The emphasis will be on applications requiring measurement of isotope ratios which differ from unity by greater than two orders of magnitude.</p> <p>Collaboration with the organisations and networks directly involved in the provision and use of isotope ratio standards, including NMIs outside Europe and key international organisations such as the IAEA and IUPAC, to ensure rapid dissemination and uptake of the outcomes of the project.</p>

NAWG: Nucleic Acid Analysis Working Group

Challenges:	<p>A number of high accuracy chemical methods are able to measure the presence of nucleic acids and, in some cases, to identify the individual nucleotide monomers. However, as all living organisms essentially use the same set of nucleotides to function, it is necessary to ‘read’ the sequence and determine the arrangement of these monomers to determine (for example) whether the sequence in question is from a genetically modified organism, a plant pathogene or foodborne pathogen. Molecular methods allow nucleic acid sequences to be determined, and where necessary, quantified and further evaluated for epigenetic differences. The development of molecular methods, including complementary hybridization, nucleic acid amplification technologies (such as the polymerase chain reaction) and sequencing coupled with the ubiquity of nucleic acids in life sciences, has meant these same methods are used for nucleic acid analysis across different specialties. Despite this, metrology and metrological considerations (such as routes to traceability and sources of uncertainty) are not commonly investigated, with those applying nucleic acid analysis typically assuming their systems are fit for purpose in this respect. Given the wide variety of applications in the nucleic acid analysis space the challenges associated with supporting in terms of measurement science are vast.</p>
Relation to food analysis	<p>Until 2021 all NAWG Key Comparisons have been in the foods analysis space Four NAWG Key Comparisons were have been in the area of food analysis and related to the needs of NMIs and DIs to provide services for detection, identification, and quantification of genetically modified organisms (GMOs) and food adulterations. NAWG activities will likely continue to support food and feed associated testing with Key Comparisons reflecting additional unmet needs, such as different matrices, species and molecular challenges (such as discriminating gene edited from natural sequences).</p>
NMIs/DIs active	<p>INRIM, LGC, BAM, PTB, TUBITAK UME, NIB, METAS</p>
Key-stakeholders	<p>The food and feed industry and regulators, instrument manufacturers governmental laboratories, reference laboratories</p>

<p>Overview</p>	<p>The focus of NAWG is to support global comparability and metrological traceability of measurement results for the analysis of nucleic acid polymer sequences, their modifications and their abundance. Nucleic acid analysis is used for a wide range of global measurements which underpin research and practical applications in most areas of life science. The various sectors in which molecular methods can be applied to identify and characterize nucleic acids and their modifications, along with the concomitant development of techniques allowing genetic sequences to be stored, modified and harnessed, has meant that nucleic acid analysis is not only used for genetic based applications, but also in the application of molecular techniques to support broader areas of bioanalysis such as protein and cellular biology.</p> <p>Since its initiation in 2015, the NAWG has primarily served the foods and feed and health sectors, although nucleic acid analysis is also important in the environmental (e.g. species/microbial surveillance) and biotechnology (spanning industrial, agricultural and pharmaceutical) sectors. These areas are also likely to benefit from NAWG activities in the future. The food authentication area is the most metrologically advanced (with respect to traceability and understanding of sources of uncertainty) in terms of routinely applied measurements and it is in this sector that NMIs have the most NAWG supported CMCs.</p>
<p>Outlook beyond 2033</p>	<p>The NAWG will considerably strengthen activities associated with molecular reference measurement procedures (likely to include the measurement of sequence structure and composition) and materials to support clinical nucleic acid analysis. These are likely to build on established capabilities for underpinning SI traceable quantitative measurements of nucleic acids copy number (per unit volume) in aqueous solutions and explore routes to apply such capacity to assist in matrix reference materials and/or reference measurement procedures on real samples; such capacity will also be of value to the other sectors such as industrial biotechnology where novel methods, such as CRISPR CAS-9 based tools, are being applied. The increasing need for genomic, transcriptomic and epigenomic analyses means that the NAWG will need to explore the development of strategies to support advanced sequencing capabilities, including for purity analysis. The measurement challenges associated with these types of ‘non-targeted’ methods are likely to increase with the development of newer, simplified sequencing technologies more suitable to less specialized settings.</p>
<p>On-going plan</p>	<p>NAWG will continue to explore this space with key comparisons to broaden the scope of measurement, both in terms of sequence type and complexity. Reference measurement systems that include methods, as well materials, to support traceability may become increasingly important to support matrix materials, or direct clinical measurements, as more nucleic acid targets are measured. How reference measurement systems can support precise and multiple quantitative nucleic acid measurements will need to be explored for this to become a reality</p> <p>Nucleic acid reference materials can differ in their composition and homogeneity in terms of sequence, fragment size and, where appropriate, matrix. This can impact on how a material may perform and characterization of these will metrics enable a better understanding of a given measurement. NAWG will explore the measurement of these characteristics using different</p>

sizing and sequencing methods to develop and compare capacity amongst NAWG members.

An important aspect of the NAWG activities will be to ensure comparisons enable capabilities with broad application. While the ubiquity of essentially the same nucleic acids across life sciences lend themselves to broader scope claims, the NAWG will need to demonstrate they are appropriate. Examples might be how capabilities demonstrated in the K86d participation, which will deal with high protein food matrices, might be applied to a clinical biopsy or how many different viral pathogen genomes will need to be evaluated to claim broader capabilities in viral measurement.

With the development of increasingly advance sequencing technologies a new paradigm in nucleic analysis has emerged. Instead of applied analytical approaches measuring a specific target, or targets, nucleic acid analysis is increasingly capitalizing on the ability of methods to measure what is present in an untargeted approach; such as when exploring the presence of a potential undefined change that may confer resistance to a cancer therapy or antimicrobial or unique genetic modification.

OAWG: Organic Analysis Working Group

Challenges:	<p>The food sector has been the highest priority sector in recent years in relation to the focus of services being developed across OAWG members. Measurements related to three key classes of compounds related to food safety: mycotoxins, pesticides and veterinary drug residues, are a core focus for the group. It is a highly regulated sector and requires reliable measurements in order to ensure product safety, quality and compliance. Key drivers in this sector include National and International Food Policies, with legislation enforced to minimize food safety risks, ensure fair trade of food and feed, and provide protection of the consumer. Implementation of new food legislation, as well as the upgrading of the capabilities of food safety inspection agencies to comply with international requirements and guidelines, are priorities for most countries in developing regions. OAWG-relevant challenges that have been identified in this sector include the provision of calibration solution CRMs to meet the requirements of ISO 17025 for metrological traceability and food matrix CRMs for validation and quality control. Production of these types of CRMs is a priority across a wide number of NMIs/DIs. There is also a lack of CRMs for a large number of combinations of food matrices with associated priority parent contaminants and/or their metabolites. A significant challenge exists to provide metrological traceability for organic compounds in diverse food matrices.</p> <p>Measurement of novel food ingredients is a growing area. Analytical measurement challenges exist relating to the unique characteristics of a great diversity of indigenous food products and “superfoods”.</p> <p>Qualitative analysis of food reference materials that involves identity confirmation of the analyte, especially when using LC-MS analysis, is another challenge.</p> <p>Challenges around food safety that are region specific are of key importance and merit a close relationship between the working group and RMOs.</p>
Relation to food analysis	<p>The OAWG priorities established in 2016 include measurement services in support of food safety, clinical biomarkers, food labeling, environmental and other organic service areas (e.g., detection of drugs of abuse and contaminants in cosmetics and analyte in mixed composition food). Measurements related to three key classes of compounds related to food safety: mycotoxins, pesticides and veterinary drug residues, are a core focus for the OAWG. The WG runs a parallel suite of comparisons for food matrix materials (polar analyte in high protein food, non-polar analyte in high fat food, analyte in mixed composition food, analyte in high carbohydrate food, non-polar analyte in food). The areas for these key comparisons were aligned with the priority areas flagged by the OAWG members.</p>
NMIs/Dis active	<p>INRIM, LGC, JSI, BAM, PTB, TUBITAK UME, METAS, EXHM, NIB</p>
Key-stakeholders	<p>The main stakeholders are the National (Agricultural, Health and Trade) regulatory agencies, accredited food testing laboratories, government-mandated food monitoring laboratories, food and feed industry, academia, trade and standards organizations, instrument and test kit manufacturers and reference laboratories.</p>
Overview	<p>The food sector is vital for the global economy. It is a highly regulated sector and requires reliable measurements in order to ensure product safety, quality and compliance. Key drivers in this sector include National and</p>

	<p>International Food Policies, with legislation enforced to minimize food safety risks, ensure fair trade of food and feed, and provide protection of the consumer. The food sector has been the highest priority sector in recent years in relation to the focus of services being developed across OAWG members. Food authenticity and adulteration issues are of growing importance for stakeholders, and these are likely to require multidisciplinary approaches across working groups.</p> <p>Measurements related to three key classes of compounds related to food safety: mycotoxins, pesticides and veterinary drug residues, are a core focus for the OAWG. Nutritional content parameters (e.g. vitamins, fatty acids), including in relation to mandatory food fortification, are also ongoing issues. Food processing and packaging migration contaminants (furans, phthalates, polycyclic aromatic hydrocarbons and mineral oil hydrocarbons) are important areas and present renewed priorities for manufactured food products.</p> <p>The demand remains for reference materials to support testing of regulated priority food contaminants (mycotoxins, pesticides and veterinary drug residues) in agricultural commodities such as grains, fruits and vegetables, animal (meat, poultry, fish) and plant (soy) proteins, dairy, honey, nuts and oils. The nutritional content parameters (vitamins, fatty acids), including mandatory food fortification, and food processing and packaging migration contaminants (furans, phthalates, PAHs, MOSH, MOAHs) are both important areas and present renewed priorities for demonstrating the compliance of manufactured food products with regulatory requirements. NMIs are also playing leading roles in providing traceable reference values for food proficiency testing schemes across this breadth of measurements, with PT providers moving away from the use of consensus values.</p> <p>The development of accurate and reliable measurements for emerging food contaminants in diverse food matrices is also needed for toxicology studies and risk assessments to support new regulation. For example, fungal and drug metabolites, processing contaminants such as the PAHs, mineral oil saturated hydrocarbons and aromatic hydrocarbons (MOSH and MOAH), environmental contaminants such as halogenated flame retardants (PFOS and PFOA), microplastics and nanoparticles are also of great interest.</p> <p>OAWG chose comparison studies based principally on the nature of the analytes in specific matrices (considering the AOAC food composition triangle) at specific quantity amounts and the relevant measurands were identified by the OAWG for each comparison.</p>
<p>Outlook beyond 2033</p>	<p>The OAWG strategic plan 2021-2030 includes Sector focus (food, clinical and environment) which are underpinned by the OAWG comparisons, progressing measurement science to underpin organic analysis such as q NMR and high resolution mass spectrometry, state of art purity assignment and improvement stakeholder engagement (ISO and its technical committees Laboratory Medicine, JCTLM, IFCC).</p> <p>State-of-the-art purity assessment is a mainstay for the OAWG as they underpin capabilities for the provision of SI-traceable calibrator materials. These will continue to be a major focus for the Track A key comparison programme supported by the BIPM. The provision of comparisons that underpin capabilities for the provision of calibration solutions is critical. This need is reflected in the BIPM Track A comparison plans. It will be supported by Track C key comparisons arising from the BIPM Capacity Building and Knowledge Transfer Programme that supports the Metrology for Safe Food and Feed in Developing Economies and which will cover a range of</p>

	<p>calibration solutions for important mycotoxin analytes. The CBKT programme has expanded to include activities in the pesticide and veterinary drug residue classes for purity assignment and multi-component calibration solutions.</p> <p>Track A key comparisons to underpin the suite of capabilities needed for matrix material related services form the third aspect of the core comparisons for the OAWG. The suite of ten matrix key comparisons planned for the next 10-year period have a strong focus on the food sector.</p> <p>Comparisons will also be planned to support the evolution of broad scope CMCs for the WG. OAWG will be examining areas where there is limited evidence to support broad CMCs and take this into account in Track A and Track C plans. Ongoing liaison with the RMOs will be important to fill gaps not addressed at CCQM level.</p> <p>The OAWG will continue to run comparisons for food matrix materials (polar analyte in high protein food, non-polar analyte in food, analyte in mixed composition food). The areas for these key comparisons were aligned with the priority areas flagged by the OAWG members.</p>
On-going plan	<p>The BIPM initiated in 2016 a Capacity Building and Knowledge Transfer program for Metrology for Safe Food and Feed (MMCBKT) in Developing Economies. This project is designed to allow NMIs/DIs within OAWG, to work together to strengthen the worldwide mycotoxin metrology infrastructure; provide knowledge transfer to scientists developing capabilities in this area and to enable NMIs/DIs in developing regions to provide calibrants, matrix reference materials and proficiency test samples that support testing activities and laboratory services for mycotoxin analysis within their countries.</p> <p>Metrology for Safe Food and Feed - Pesticides and Veterinary Drug Residues project, started in 2020, is designed to allow NMIs within OAWG, to work together to strengthen metrology for food safety infrastructure; provide knowledge transfer to scientists developing capabilities in this area, including periods as visiting scientists at the BIPM; and enable NMIs to provide pesticide and veterinary drug calibrant and food matrix reference materials and proficiency test materials to support food testing laboratories within their countries. The project has support from a number of NMIs who are providing scientific expertise and materials to the project. The technical activities at the BIPM will focus on Calibrants and providing appropriate training and knowledge transfer. A new project on calibrators for pesticides residue analysis will commence in 2024.</p> <p>The OAWG will continue to run comparisons for food matrix materials (polar analyte in high protein food, non-polar analyte in food, analyte in mixed composition food). The areas for these key comparisons were aligned with the priority areas flagged by the OAWG members. OAWG has introduced task groups for each sector focus including Food. Task groups are performing horizon scanning activities, identifying, and proposing suitable comparisons that would underpin CMCs of members with services in the Food Sector during the strategic period.</p>

IAWG: Inorganic Analysis Working Group	
Challenges:	<p>The Inorganic Analysis Working Group (IAWG) plays a crucial role in ensuring the comparability and traceability of inorganic components in food analysis.</p> <p>The IAWG faces multiple challenges in the food sector, such as the emerging contaminants, for example nanoparticles and novel packaging materials, introduced into the food supply chain. For these new inorganic contaminants, the development of standard methods is necessary to ensure consistency and comparability of the results.</p> <p>Obtaining high quality reference materials for complex food matrices, containing various inorganic components at different levels, can be very challenging. For this reason, one of the main objectives of the IAWG is to develop certified reference materials for different types of food matrices and standards for calibrating instruments.</p> <p>Achieving low detection limits for inorganic contaminants, such heavy metals, is critical for food safety. Sensitive analytical methods are needed for detecting these contaminants even at trace level.</p> <p>Collaborations with other working groups, such as OAWG or SAWG (surface analysis working group) on projects that involve inorganic and organic contaminants and nanoparticles in foods, are challenging, but beneficial for the sharing of knowledge, expertise and resources. In this way the development of new measurement techniques for food analysis could benefit from interdisciplinary input.</p>
Relation to food analysis	<p>In the CCQM-IAWG strategy document 2021-2030 food safety is specifically mentioned as one of the major research areas of the IAWG.</p> <p>In this document, special importance is due to the elemental speciation in food analysis. The toxicity of elements in food often depends on the species of elements present. For example, methylmercury is of greater concern than inorganic mercury, inorganic arsenic is more toxic than arsenic organic compounds. For this reason, the IAWG works on elemental speciation in food, especially through the organization of key comparisons and pilot studies, such as the CCQM-K158/P200 (Part B) "Determination of inorganic arsenic in rice flour" and P-215 "Speciation of arsenic in seafood".</p> <p>The organization of key comparisons and pilot studies in food analysis is one of the major activities of the IAWG related to food analysis. This is crucial for ensuring food safety, quality control, and compliance with regulatory standards.</p>
NMIs/Dis active	INRIM, LGC, JSI, BAM, PTB, TUBITAK UME, GUM, METAS, EXHM
Key-stakeholders	The main stakeholders are government regulatory agencies such as the European Food Safety Authority (EFSA), food testing laboratories and reference laboratories, food industry, academic and research institutes, standardization bodies (for example ISO, IUPAC), international organizations.
Overview	<p>The IAWG works to promote global comparability of inorganic analysis measurements in different fields among its members institutes.</p> <p>In the food area, special attention is given to the analysis of heavy metals, elemental species, nanoparticles, nano- and microplastics and</p>

	<p>metalloproteins, which contain metal ions as part of their structure.</p> <p>Different key comparisons and pilot studies have been completed using food matrices, which fall into the category "high organic matrices".</p> <p>As examples, toxic and essential elements have been measured in bovine liver (CCQM-K145/P183), different elements were measured in rice flour (CCQM-K158/P200, Part A), the speciation of arsenic was carried out in seafood (P215).</p> <p>Currently, the IAWG supports approximately 2000 approved CMC claims. Most of these claims are in the category "Food" (23% of the total CMC claims).</p>
<p>Outlook beyond 2033</p>	<p>The strategic plan 2021-2030 of the IAWG focuses on food safety, climate change and environment, health and life science, energy and advanced manufacturing.</p> <p>The IAWG will continue to improve the comparability of measurements, ensuring the metrological traceability for the inorganic analysis. Further advances will be provided in purity assay studies, calibrants preparation and matrix reference materials. These services are essential to support agriculture and food manufacturing, health, environment and regulation.</p> <p>The IAWG plans to focus continuing efforts on: nanoparticles metrology, metalloprotein measurements and elemental speciation. All these measurements are required from many stakeholders, also from those in the food sector.</p> <p>To support the development of capabilities at NMIs and Dis in the area of food analysis, the IAWG will continue to organize key comparisons and pilot studies, concerning the measurements of elements in food matrices.</p>
<p>On-going plan</p>	<p>The on-going plan includes an interdisciplinary approach for topics regarding food analysis, such as nanoparticles, nano- and microplastics and metalloproteins. A close collaboration between the IAWG and other CCQM working groups, such as OAWG, SAWG or PAWG, has already started. They represent together the CCQM-Task Group on Food metrology.</p> <p>In addition, the IAWG cooperates with the regional metrology organizations (RMOs) for different comparisons, also in the food area. Some of these comparisons (SIM.QM-S11/P25 "Trace elements in yerba mate" and SIM.QM-S18/P27 "Cadmium and lead in cacao powder") are in progress.</p> <p>The IAWG plans further a new key comparison on "Elements in pork", that will be discussed and organized in the near future.</p>

PAWG: Protein Analysis Working Group	
Challenges:	Proteins are dynamic and heterogeneous biomolecules whose accurate quantification is key in sectors such as food, health and biopharma. Unravelling protein structures, interactions, and their relationship to function are critical toward accurate and comparable protein measurements. However, the metrology community has only recently started to address higher-order structures of proteins. Also, the definition of the measurand is not trivial for heterogeneous molecules measured by different techniques. This project will investigate the overall protein structure and its influence on measurements and function. It will provide a metrology framework and guidelines to better define the measurands, analytical targets and estimate measurement uncertainty.
Relation to food analysis	Depending on which forms of the protein are targeted and the measurement principles, protein measurement may be affected by these modifications, leading to discrepant results. Therefore, reliable and comparable measurements and confidence in data for proteins are crucial in all Life Science sectors including food industry and food safety. Given the complexity and heterogeneity of proteins, one of the main challenges is defining the target intended to be measured, namely the measurand. This is further complicated by the different techniques used for their measurement, relying on analytical targets that usually differ from the measurand.
NMIs/Dis active	INRIM, LGC, JSI, BAM, PTB, TUBITAK UME
Key-stakeholders	The food and feed industry and regulators, instrument manufacturers governmental laboratories, reference laboratories
Overview	In the food safety sector, 13 of the 14 priority food ingredients that trigger allergic responses are related to their protein content. As avoiding specific food ingredients is the only way to prevent an allergic reaction, the accurate identification, detection and quantification of these protein allergens are essential for food safety, fraud management, risk assessment and regulatory compliance. In the health sector, proteins serve as clinical biomarkers for disease prognosis, diagnosis, and monitoring. Numerous assays, mainly immunoassays, with different measurement principles have been developed to detect or quantify biomarkers. Reliable detection, quantification, and comparability of measurement results in biological matrices are essential for healthcare and safety.

SAWG: Surface Analysis Working Group

Challenges:	<p>Surface analysis metrology faces several challenges, both technical and practical, which can impact the accuracy, reliability, and applicability of the obtained data. Some of the challenges associated with surface analysis metrology include:</p> <ul style="list-style-type: none"> • Limited Depth Profiling: Techniques that provide surface-sensitive information may have limitations in depth profiling. Understanding subsurface properties without damaging the sample can be challenging, particularly for materials with complex structures. • Time and Cost: Certain surface analysis techniques can be time-consuming and expensive. The investment in specialized equipment, skilled personnel, and the time required for analysis can be limiting factors for widespread use. • Complexity of Multilayered Systems: Surface analysis of multilayered materials or complex structures can be challenging. Distinguishing between different layers, understanding interfaces, and characterizing each layer's properties individually can be intricate. • Quantitative Analysis: Achieving accurate quantitative analysis, particularly in terms of elemental or chemical composition, can be challenging. Calibration standards and correction factors are needed, and variations in sample composition can affect the reliability of quantitative results. • Integration of Multiple Techniques: Combining different surface analysis techniques for a comprehensive understanding of a material's surface properties can be challenging. Integration of data from various methods may require careful alignment and correlation. • Data Overload: Advanced surface analysis techniques can generate large volumes of data. Analysing and managing this data efficiently, especially in the context of complex materials or systems, can pose a significant challenge. The digitalization and AI will contribute in the data analysis <p>Addressing these challenges requires ongoing research and development efforts, advancements in instrumentation, and the continuous improvement of analytical methods. Collaboration between researchers and industry experts is crucial to overcoming these challenges and advancing the field of surface analysis metrology.</p>
Relation to food analysis	<p>Characterizing food packaging is crucial for ensuring the safety, quality, and effectiveness of packaging materials used in the food industry. Various aspects of food packaging need to be analyzed and understood to meet regulatory standards, maintain product integrity, and address sustainability concerns.</p> <p>Particle food contaminants present in food, organic and inorganic.</p>

NMI/Dis active	INRIM, LGC, JSI, BAM, PTB, TUBITAK UME
Key-stakeholders	The food and feed industry and regulators, instrument manufacturers governmental laboratories, reference laboratories
Overview	<p>Surface analysis characterization of plastic packaging is crucial for several reasons, as it provides valuable information about the material properties, quality, and performance of the packaging.</p> <p>Different techniques contribute to the characterization of plastic materials such as:</p> <ul style="list-style-type: none"> • Vibrational spectroscopy (Raman, FTIR): Determines the chemical composition of the plastic. The identification and counting of the number of microplastics compared to their size. • Differential Scanning Calorimetry (DSC): Measures heat changes associated with thermal transitions in the material, such as melting, crystallization, or amorphous transitions. • Thermogravimetric Analysis (TGA): Measures changes in weight and temperature as a function of time under controlled conditions. • Microscopy techniques (TEM, SEM): Allows you to observe the microstructure of the plastic surface at the nanometer level. • Contact angle: measures the wettability of the surface. • UV-Vis Spectroscopy: Analyzes light absorption in the ultraviolet-visible range to determine the presence of additives and colorants. • XPS (X-ray Photoelectron Spectroscopy): XPS provides information about the elemental composition, chemical states, and electronic states of the surface of a material. It is surface-sensitive and can provide details about the top few nanometers of a sample. • XRD (X-ray Diffraction): XRD provides information about the crystal structure of a material. It reveals the arrangement of atoms in a crystalline structure, allowing the identification of crystal phases, lattice parameters, and crystal orientation. • Nuclear magnetic resonance (NMR) spectroscopy: Provides information on the molecular structure and configuration of polymers.
Outlook beyond 2033	<p>Here are some key reasons highlighting the importance of surface analysis in the characterization of plastic packaging:</p> <ul style="list-style-type: none"> • Material Composition and Identification: Surface analysis helps identify the composition of the plastic material used in packaging. Different plastics have distinct chemical compositions, and knowing the exact material is essential for recycling and waste management. It enables manufacturers to ensure that the packaging material meets regulatory standards and is suitable for its intended purpose. • Quality Control: Surface analysis techniques can detect defects, impurities, or irregularities on the surface of plastic packaging. This information is crucial for maintaining quality control during the manufacturing process. Identifying defects early in the production process helps prevent issues

	<p>such as leaks, contamination, or compromised product integrity.</p> <ul style="list-style-type: none"> • Adhesion and Coating Performance: Understanding the surface properties helps assess the adhesion of coatings or labels on the plastic packaging. Proper adhesion is vital for the durability and appearance of the packaging. Surface analysis aids in evaluating the effectiveness of surface treatments or coatings applied to enhance barrier properties, UV resistance, or printability. • Barrier Properties: The surface of plastic packaging plays a significant role in determining its barrier properties against oxygen, moisture, and other environmental factors. Surface analysis can provide insights into these barrier properties. This information is essential for packaging materials used in food, pharmaceuticals, and other sensitive products, where maintaining product freshness and stability is critical. • Interaction with Contents: Some products can interact with the packaging material, affecting their quality or safety. Surface analysis helps assess the potential migration of substances from the packaging into the product. This is particularly important in the food and pharmaceutical industries, where strict regulations govern the materials that come into contact with consumable products. • Recyclability and Sustainability: Surface analysis aids in evaluating the recyclability of plastic packaging. Understanding the surface characteristics helps in designing materials that are easier to recycle and contribute to sustainable packaging practices. It supports the development of environmentally friendly packaging solutions by providing insights into the material's compatibility with recycling processes. <p>The information obtained through surface analysis metrology on plastic packaging is essential for ensuring material quality, performance, and adherence to regulatory standards. It contributes to the development of safer, more sustainable, and efficient packaging solutions across various industries. Could contribute, in the vision of circular economy, in the reduction of food waste</p>
On-going plan	<p>Microplastics and nanoplastics have become emerging particulate anthropogenic pollutants and rapidly turned into a field of growing scientific and public interest. These tiny plastic particles are found in the environment all around the globe as well as in drinking water and food, raising concerns about their impacts on the environment and human health. To adequately address these issues, reliable information on the ambient concentrations of microplastics and nanoplastics is needed.</p>

EURAMET e.V.
Bundesallee 100
38116 Braunschweig
Germany

Phone: +49 531 592 1960
Fax: +49 531 592 1969
E-mail: secretariat@euramet.org



The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

EURAMET e.V. is a non-profit association under German law.