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RESEARCH ARTICLE

TRANSFORMING INFRASTRUCTURE INTO SERVICES: A CASE STUDY OF METROFOOD-RO IMPACT ON THE FOOD AND HEALTH SECTOR IN ROMANIA

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Abstract: METROFOOD-RO is a Research Infrastructure operating in the "Health & Food" field in Romania, and it serves as an integral component of the pan-European METROFOOD Research Infrastructure (METROFOOD-RI). Its primary mission is to advance metrology within the food and nutrition sector. This infrastructure comprises a well-organized network with nine partners, including four universities, four research and development institutes, and one research center. These collaborative partners engage in research activities and provide advanced services for various user categories, such as academic and research institutions, food inspection and regulatory agencies, policymakers, food industry operators, and the general public. METROFOOD-RO offers a comprehensive range of services, including Food, Environmental, and Food Packaging Analysis. These services cover the analysis of contaminants, microbiological assessments, evaluations of nutritional properties, measurements of technological parameters, and detection of authenticity and fraud. Moreover, METROFOOD-RO is equipped to provide agro-ecosystem characterization services, with a specific focus on characterizing environmental matrices such as water, soil, sediments, and air, with an emphasis on identifying chemical and microbiological contaminants. The objective of this paper is to present METROFOOD-RO's service portfolio, categorized into food safety, food quality, food authenticity, nutritional properties, food packaging and agro-ecosystem.

Keywords: METROFOOD-RO, services, food safety, food quality, food authenticity, packaging testing

 Received October /Accepted December 2023

RESEARCH ARTICLE

Introduction

Research, development, and innovation have gained prominence on political agendas as mechanisms to increase economic growth. Within the European Union (EU), the 'Europe 2020' strategy incorporates the Innovation Union flagship initiative, which seeks to elevate Europe's standing in scientific achievements. This initiative focuses on creating a unified European Research Area and advancing the development of critical European research infrastructures (RIs) (Florio and Sirtori, 2016).

According to the European Research Infrastructure Consortium (ERIC) Regulation (Council Regulation [EC] No 723/2009 of 25 June 2009), the term "research infrastructure" encompasses facilities, resources, and associated services employed by the scientific community for conducting cutting-edge research in their specific domains. This includes significant scientific apparatus or instrument collections, knowledge-based resources like collections, archives, or systems for scientific information, as well as Information and Communications Technology-based infrastructures such as Grid computing, software, and communication, or any other distinct entity essential for attaining research excellence (Hegerty *et al*., 2022).

In the case of food and health, an RI can facilitate the use of scientific data to demonstrate the connections between various factors, including food consumption, food production, population growth, limited natural resources, climate change and health, as well as related issues such as obesity, cancer, cardiovascular disease and malnutrition (Timotjevic *et al*., 2021).

METROFOOD-RI, which is a pan-European distributed RI in the Food and Health field, is dedicated to promote Metrology in Food and Nutrition. Led by Italy, this initiative includes the participation of research institutions, including research centers, national metrology institutes, and universities, from 18 EU-Member States and Associated Countries (Stelzl *et al*., 2023).

The METROFOOD-RO national node is an integral part of the European METROFOOD-RI network. The establishment of the METROFOOD-RO National Node aims to develop and enhance the Research, Development, and Innovation capabilities and the offer of scientific services. It also aims to develop the necessary tools to enhance the testing performance

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of agri-food products, enabling Romania to meet European requirements in the field of food safety and security.

METROFOOD-RO comprises nine partner institutions, including universities, Research & Development (R&D) Institutes, and a Research Centre. The four universities members of Metrofood-RO are: University “Dunarea de Jos” of Galati, University of Agronomic Sciences and Veterinary Medicine of Bucharest, University of Life Sciences “King Mihai I” from Timisoara, and University of Bucharest. The four R&D Institutes are: the National Institute of R&D for Food Bioresources – IBA Bucharest, which serves as the coordinator of the national node, the National Institute of Research & Development for Machines and Installations Designed for Agriculture and Food Industry – INMA Bucharest, the National Institute for Research & Development of Isotopic and Molecular Technologies – INCD-TIM Cluj-Napoca, and INCDO-INOE 2000 subsidiary Research Institute for Analytical Instrumentation – ICIA Cluj-Napoca. The ninth partner is Centre for Gene and Cellular Therapies in the Treatment of Cancer – OncoGen Timisoara.

Some of the benefits of establishing this METROFOOD-RO National Node include: (1) creating a sustainable consortium to provide high quality research services to stakeholders in the food supply chain, (2) enhancing scientific knowledge and promoting cooperation and interaction among various stakeholders, (3) creating a common database of information and knowledge, (4) pursuing a broad, multidisciplinary approach to project proposals in different national and international programs, (5) providing a strategic opportunity for the development of the Romanian agri-food sector, which has significant potential and proven socio-economic impact across interconnected sectors, (6) implementing common cooperation strategies to integrate resources and expertise for the benefit of society, (7) promoting the acceleration of scientific discoveries and innovation, (8) promoting the authenticity and safety of food production through high-quality laboratory tests, which contribute to consumer trust (metrofood.ro).

The aim of this paper is to present the main services offered by METROFOOD-RO to the Romanian food industry, highlighting the importance of food authenticity, food safety, food quality, nutrition, food packaging and environmental issues.

 Received October /Accepted December 2023

RESEARCH ARTICLE

Sustainability of Research Infrastructure

The main objective of a RI is to guarantee the quality and excellence of the services offered. It is widely recognized that excellence serves as a primary catalyst for the advancement of RI. This commitment to excellence should be consistently maintained throughout the life of RI, encompassing both research efforts and the development of new technologies for the benefit of the RI user community. Another important aspect concerns the development of human capital within the RI ecosystem. This encompasses a diverse range of individuals, including users, managers and operators, among others. When conceptualizing future RIs, it is imperative to consider the different roles that individuals might assume at different points in the RI life cycle. A key challenge and take-away message therefore underlines the importance of ensuring that individuals with the necessary skills and expertise are positioned appropriately and at the appropriate times (Ribeiro, 2020).

A significant challenge for RI is to increase the cohesion and sustainability of distributed networks and infrastructures within a unified, pan-European framework or infrastructure. This integrated infrastructure should formulate a comprehensive strategy for addressing long-term and large-scale challenges, while collaborating with local and regional monitoring programs to increase the overall quality and sustainability of the data they contribute. The sustainability of a RI aims to guarantee a minimum period of operational capacity and data availability within the system (Farcy et al., 2019). For the Metrofood-RO National Node, a minimum sustainability period of 5 years was established.

In order to ensure the long-term sustainability of research infrastructures, European Strategy Forum on Research Infrastructures (ESFRI) has introduced a series of recommendations, including:

- Encouraging and sustaining excellence throughout the entire life cycle of RIs, using all appropriate methods, while creating the necessary framework conditions and opening RIs to a global audience.
- Ensure that RIs have access to the right people with the right skills and expertise, at the right time, by strengthening and harmonizing national research and education systems to ensure the availability of essential skills.
- Promoting a cohesive vision for the coordinated operation of RIs and e-infrastructures in Europe, aiming to provide cost-effective services to user communities.

- Maximizing the potential of RIs as nodes for innovation by integrating their development strategies into innovation policies at both national and European levels.
- Establish effective mechanisms for assessing the wider economic and social value of RI and embed these benefits in dialogues between policy makers, the scientific community and society at large.
- Create favorable framework conditions for effective governance and sustainable and long-term financing of RIs at every stage of their life cycle, while ensuring effective management.
- Encouraging greater coordination at both national and European level when designing processes for planning and supporting national and pan-European RIs, thereby increasing their strategic importance (ESFRI, 2017).

The METROFOOD-RO Consortium, in its role as a service provider, aims to offer consistent and standardized services, facilitating the creation of long-term, high-quality multidisciplinary datasets. The organization and structure of this consortium are essential components of the strategy to maintain a sustainable research infrastructure (Farcy *et al*., 2019).

Services provided by METROFOOD-RO

Food authenticity services

Foods available in the global market can be subject to fraudulent activities, by various entities such as producers, co-packers, distributors, and others participating in the national or international trade network (Gizaw *et al*., 2019). Food fraud include practices such as substitution, addition, adulteration, and alteration. There has been a rising occurrence of adulteration in food, food ingredients, and commodities in recent years, which is believed to be linked, at least in part, to the globalization of supply chains and the implementation of complex distribution systems (Brooks *et al*., 2021). The assessment of food authenticity holds significant importance for the quality control and food safety. Authenticity testing serves as a quality criterion for both food products and their constituent ingredients, assuring the legislative protection of regional food products (Danezis *et al*., 2016). Food fraud cases, motivated primarily but not only by financial gain, can have direct or indirect implications on food safety and consumer health. Illegally incorporating or substituting ingredients for economic or nutritional advantages can go undetected, posing potential life-threatening risks. Furthermore,

inadequate product labeling fails to inform consumers about harmful allergens, thereby increasing health risks, such as not labeling the presence of nut products or falsely claiming gluten-free status (Brooks *et al*., 2021). The broader context of food fraud underscores the need for vigilance and regulatory measures to protect the integrity of our food supply and the safety of consumers.

To prevent these fraudulent practices, the METROFOOD-RO node has developed a series of methods to document authenticity and identify food fraud. Figure 1 illustrates the methods used by national node METROFOOD-RO for detecting food authenticity and fraudulent practices.

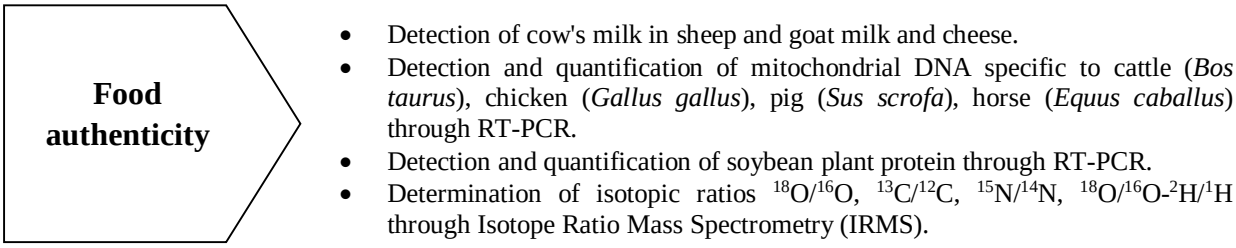


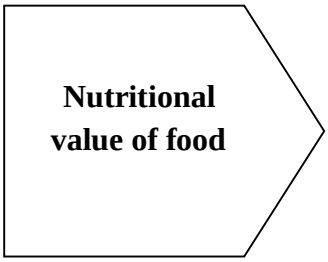
Figure 1. Food authenticity services provided by METROFOOD-RO

Nutritional quality of food products services

As part of food quality assessment, the nutritional value is a product recommendation card as it provides essential information needed by the consumer on nutrient content. Nutritive value is a measure of the ratio of key carbohydrate, fat, protein, mineral and vitamin elements in foods products, designed to inform consumers. The nutritional composition of food plays a major role in maintaining human health and in the evolution of non-communicable diseases (Adhikari *et al*., 2022). The study of Global Burden of Disease (GBD) from 2017 on data collected over 27 years (1990-2017) from 195 countries showed that globally, about 20% of deaths associated with nutritional deficiencies could be prevented by improving diet. They estimated that in 2017 dietary risk factors were responsible for 11 million deaths and 255 million disability-adjusted life years (DALYs) (Afshin *et al*., 2019), surpassing that of smoking-related deaths. The nutritional value of food can be assessed based on primary essential nutrients like water, fibre, proteins, fats, carbohydrates, vitamins, dry matter, and minerals, as well as secondary compounds known as "phytonutrients." There are approximately 5,000 to 10,000 secondary compounds found in plants

that are recognized for their health-enhancing and protective properties, making them crucial for overall well-being (Bansal, 2017).

To ensure the nutritional quality of food products in Romania, the METROFOOD-RO node has the capacity to precisely assess various nutritional parameters using a variety of techniques, many of which are accredited methods. These methods are presented in Figure 2**.**



- Protein content
- Crude fiber content
- Dietary fiber content
- Fat content
- Sugar content
- Salt content
- Carbohydrates content
- Determinations of vitamins
- Minerals content
- Lipid profile determination
- Fat acids content
- Aminoacids content
- Nutritional value and energetic value estimation

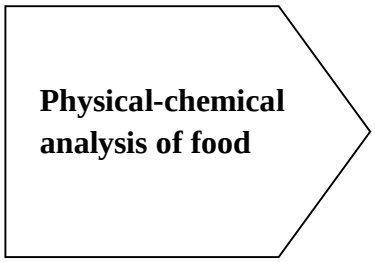
Figure 2. METROFC

Physical-chemical analysis of food

Physical and chemical testing of food is made by an array of methods for evaluating food quality and safety. It uses technique and instruments to examine the physical and chemical properties of food through various experiments, which allow the determination of various constituents and their concentrations in the food products (Lihua et al., 2019).

The chemical and physical analysis of foods represent is crucial within a quality assurance program in food processing, starting from the assessment of ingredients and raw materials, continuing through the processing, and concluding with the evaluation of finished products. Moreover, chemical and physical analysis plays a key role in the development of new food products, the formulation of recipes, the assessment of novel food production methods, and the identification of the nonconformities in food products (Nielsen, 2017).

Figure 3 systematically presents the physical-chemical analysis of food products offered by METROFOOD-RO, with many of them being accredited methods.



- Density (foods and alcoholic beverages)
- Hectoliter mass
- Porosity of the bread and bakery products
- Bread core elasticity
- Volume of bread and bakery products
- Wheat glassiness
- Ash content
- Acidity
- Alkalinity
- Soaking Time
- Conductivity of food products
- Alcohol concentration
- Free and total sulfur dioxide from alcoholic beverages
- Total dry extract content
- Water hardness
- Volatile acidity
- Furfural determination
- Acetaldehyde from alcoholic beverages
- Styrene and phthalates content
- Nature and concentration of free radicals
- Water content in oils
- Antioxidant capacity
- Total polyphenol content
- Deformation Index, Wet gluten content, Gluten index
- Hagberg Method – Perten falling number
- Rheological properties
- Boiling analysis of pasta
- Baker's yeast growth
- Peroxide value
- Iodine value
- Saponification value
- Zeleny sedimentation test
- Grain flotation index
- Total soluble solids
- Collagen content
- Organoleptic analysis
- Texture profile analysis

Figure 3. Physical-chemical analyses offered by METROFOOD-RO

Food safety

Food safety is a critical concern that impacts the food markets, but also health and wellbeing of individuals and communities, and modern food safety systems are assuring that food will not affect consumer health (Helmy *et al*., 2023; Cakmakci and Cakmakci, 2023). To address this issue effectively, it is essential to adopt a comprehensive approach to food safety. This approach should encompass not only the immediate concerns related to foodborne illnesses

but also the broader aspects of sustainability and the health implications associated with methods of food production. In essence, food safety represents a multifaceted challenge that demands a holistic, one-health approach to safeguard the well-being of individuals, communities, and the environment (Helmy *et al*., 2023).

Food safety within the food market remains a key concern of public health, as it has repercussions for individuals of all ages, backgrounds, genders, and income brackets worldwide. Both local and global food markets continue to exert considerable influence on public health and food safety. The modern food supply chains often span multiple international borders, thereby amplifying the globalization of health-related risks (Gizaw, 2019).

According to Fung *et al*., 2018, the food safety faces four major challenges, namely microbial contamination, personal hygiene, environmental hygiene and chemical contamination. Food safety control plays a crucial role in verifying that products respect the hygiene standards regarding microorganisms, parasites, chemicals, and other foreign substances. Identifying critical control points in food production is an effective way to minimize hazards and associated health risks to consumers. Consequently, international codes and standards such as Global Good Agricultural Practices (GAP), International Organization for Standardization (ISO 22000), and Codex Alimentarius are recognized for their proactive approach in reducing risks (Todorovska and Shosholovski, 2023).

1. Microbiological contamination

Food can support the growth of various microorganisms that have the potential to cause foodborne diseases. These illnesses can range from mild cases of gastroenteritis to more severe conditions like neurological, hepatic, and renal syndromes, often triggered by toxins produced by disease-causing microorganisms. Among foodborne bacterial agents, *Staphylococcus*, *Salmonella*, *Campylobacter*, *Listeria*, *Vibrio*, *Bacillus*, and certain strains of *E. coli* and *Clostridium*. For instance, in countries like the United States and France during the last decade of the 20th century, *Salmonella* was the most prevalent cause of bacterial foodborne illness, accounting for 5,700 to 10,200 cases, followed by *Campylobacter* with 2,600 to 3,500 cases, and *Listeria* with 304 cases (Fung *et al*., 2018).

To ensure the microbiological safety of food products, the Romanian node METROFOOD-RO has the capability to identify, though accredited methods, the presence of

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various microorganisms, viruses, and fungi. The Figure 4 systematically illustrates the services offered by METROFOOD-RO for detecting pathogenic and non-pathogenic microorganisms.

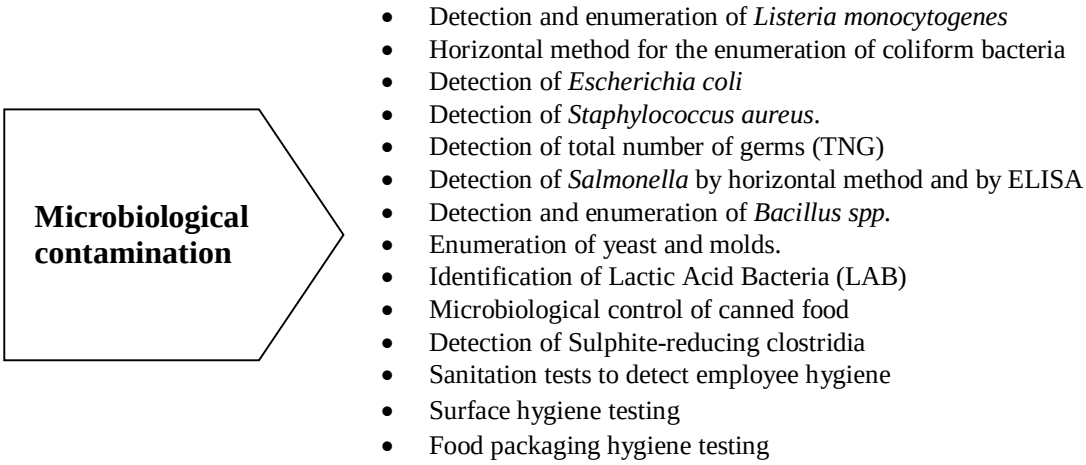


Figure 4. METROFOOD-RO services for detecting microbiological contamination of food

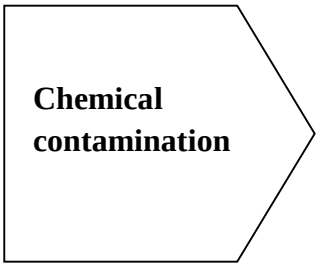
Microbiological examination of food constitutes is an integral component of food safety management and conformity assessments. It involves the establishment of microbiological criteria and the evaluation of control strategies, all within the framework of Hazard Analysis and Critical Control Point (HACCP) systems. When conducting microbiological tests on food, two types of methods are employed: rapid and conventional (Hungaro *et al*., 2014). Conventional methods, which are labor-intensive and time-consuming, due to the cultivation in selective enrichment media, followed by confirmation and biochemical tests (Karanam *et al*, 2008) are named as due to their long-standing history and official adoption by most food microbiology laboratories, being in use for many years (Hungaro *et al*., 2014).

2. Chemical contamination

Chemical contamination can occur at various stages throughout food processing, packaging, transportation, and storage. Additionally, it can stem from environmental factors like toxic metals, polychlorinated biphenyls, and dioxins, or result from the deliberate use of substances like pesticides, veterinary drugs, and food packaging materials at pre or post-processing stages. The consequences of chemical contaminants in food can range from acute effects following a single exposure, like gastrointestinal illnesses, to chronic conditions

stemming from prolonged and repeated exposure, such as liver cancer resulting from ongoing mycotoxin exposure (Choudhury *et al*., 2022).

To detect the presence of chemical contaminants and prevent consumer exposure to such substances, the METROFOOD-RO node employs a range of detection methods, many of them being accredited. The Figure 5 provided METROFOOD-RO's capabilities in detecting chemical contamination.



- Detection of heavy metals by GF-AAS Spectroscopy
- Detection of Hg through thermal desorption coupled with atomic absorption spectrometry (TD-AAS).
- Detection of organochlorine pesticides by Gas Chromatography coupled with mass spectrometry (GC-MS) and Gas Chromatography with electron capture detector (GC-ECD)
- Detection of dioxins and furans Gas chromatography coupled with triple quadrupole mass spectrometry
- Detection of PAHs by HPLC with fluorescence detector (HPLC/FLD)
- Determination of acrylamide by Gas chromatography with tandem mass spectrometry (GC-MS/MS)
- Detection of veterinary drugs residues by Gas Chromatography coupled with mass spectrometry (GC-MS)
- Detection and quantification of mycotoxins: DON, AFT, ZEN, OTA, AFM_1 (ELISA), B_1, B_2, G_1 (LC-FLD), patulin (HPLC/DAD)
- Detection of genetically modified organism (GMO)
- Detection of residues of hormones (LC-MS)
- Detection of physical contaminants

Figure 5. Chemical contamination analyses provided by METROFOOD-RO

Mitigating chemical contaminants in food presents a significant challenge for both the food industry and regulatory authorities due to the potential health risks associated with them. Factors like climate change, globalization, and the food manufacturing process all play a role in the growing occurrence of chemical contaminants within the food supply chain. To reduce the health hazards linked to food contamination, it is crucial to implement effective measures aimed at minimizing exposure to these chemical agents by closely monitoring and controlling their sources of origin. The commonly reported chemical contaminants in food include, among others, heavy metals, pesticides, and mycotoxins (Onyeaka et al., 2024).

Testing and characterization of food contact materials

RESEARCH ARTICLE

Food contact materials (FCMs) have the potential to release substances that migrate into food products. These materials are a significant source of chemical contamination in food and can contribute substantially to chronic chemical exposure. The migration of contaminants into food depends on various factors, including the composition of the material, package size, temperature, storage duration, the nature of the food. Sometimes, improper packaging methods, storage, or handling can lead to structural defects in packaging, resulting in swelling of packaging materials or sealants leading to leaching into the food product. Common migrants from contact materials include chemicals like benzene, bisphenol A (BPA) (Lebelo et al., 2021), phthalates, acetaldehyde, formaldehyde, heavy metals, monomers (Regulation CE no. 10/2011). According to the Regulation CE no. 1935/2004, the food contact materials include: Active and intelligent materials and articles, adhesives, ceramics, cork, rubbers, glass, ion-exchange resins, metals and alloys, paper and board, plastics, printing inks, regenerated cellulose, silicones, textiles, varnishes and coatings, waxes, wood.

The METROFOOD-RO national node is equipped with laboratories dedicated to testing and characterizing materials used in the food industry. An overview of METROFOOD-RO food contact materials testing services is illustrated in the Figure 6.

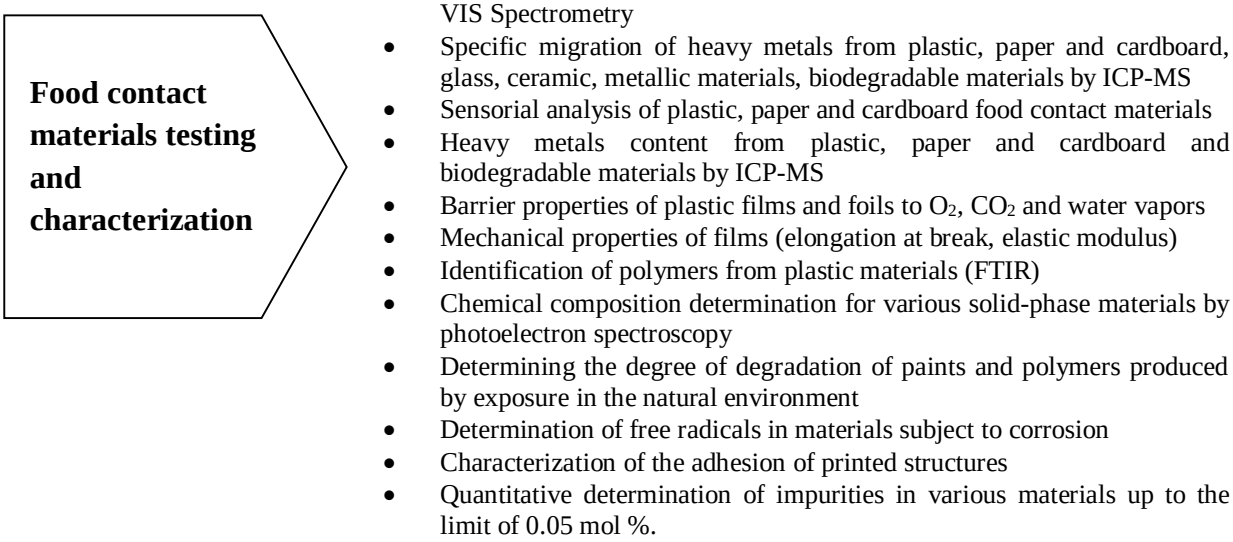


Figure 6. Analysis of the food contact materials and food contact articles

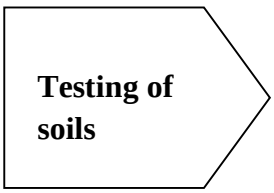
RESEARCH ARTICLE

Environment contamination

Environmental contaminants are substances found in the environment at concentrations exceeding permissible limits, causing adverse effects on the environment and posing risks to human, animal, and plant health. The industrialization and excessive use of chemical fertilizers have led to the contamination of our environment with various types of contaminants. Common environmental contaminants include polyaromatic hydrocarbons, heavy metals, organic solvents, pesticides, and inorganic solvents (Savita *et al*., 2019). The well-being of human health is significantly influenced by both environmental contamination and food safety. Numerous studies are undertaken to examine the transfer of contaminants from the environment into food, ultimately affecting human health. Considering the critical significance of environmental factors and food safety, it is unsurprising that numerous studies have been published in this field (Jiang *et al*., 2021).

Depending on the nature of the pollutants and their subsequent impact on environmental components, pollution can be categorized as follows: air pollution, water pollution, soil/land pollution, noise pollution, radioactive pollution and thermal pollution (Rai, 2016).

The METROFOOD-RO national node has the required infrastructure for identifying a wide range of chemical and microbiological contaminants in water, soil, and air. These services are detailed in the Figures 7 – 9.



- Determination of heavy metals by flame atomic absorption spectrometry (FAAS)
- Determination of the content of petroleum hydrocarbons / mineral oils by gas chromatography (GC-MS)
- Determination of total hydrocarbon content
- Determination of water content
- pH

Figure 7. Services offered by METROFOOD-RO for chemical analysis of soils

The severe issue of soil contamination is affecting the safety of food, the environment, public health, and the potential for sustainable social development. Soil pollution often involves the presence of heavy metals, pesticides, chemicals, radioactive waters, that far exceed acceptable pollution standards (Sethi and Gupta, 2020).

RESEARCH ARTICLE

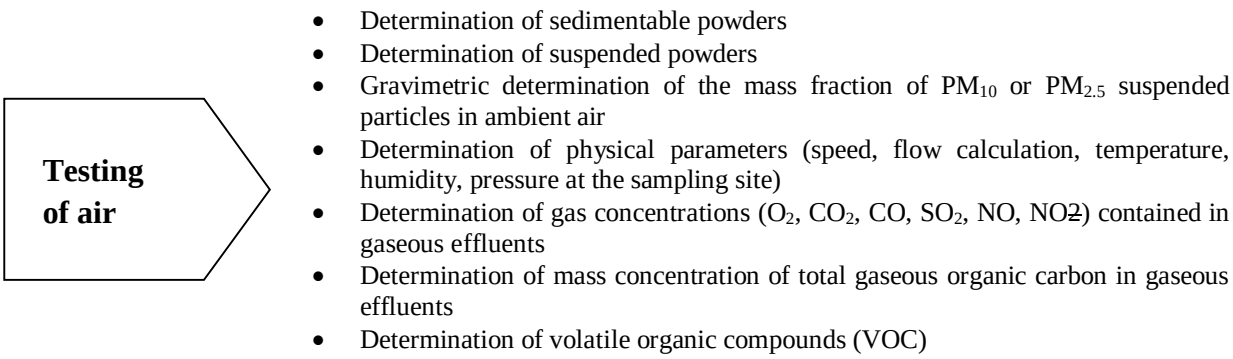


Figure 8. Services offered by METROFOOD-RO for the chemical analysis of air

Air serves as a significant potential source of contamination across various sectors, including medicine, pharmaceuticals, agriculture, the food industry, and more. Throughout the various stages of food production and processing, contamination can occur through pollutants present in the air, including suspended particles (leading to physical contamination), combustion byproducts (nitrogen oxide, carbon monoxide, carbon dioxide, sulfur oxide), volatile organic substances (causing chemical contamination), and biological contaminants like bacteria, viruses, molds, and mites (Moracanin *et al*., 2019).

Water resources play a crucial role in influencing the quality parameters of water for various activities within food systems, including agricultural production, aquaculture, food processing, and food consumption. This contribution to food security aligns with the Zero Hunger Sustainable Development Goal (SDG2) (Linderhof *et al.*, 2021). In the food industry, water is an essential resource serving a multitude of purposes. Often underestimated, water plays a crucial role in numerous operations of food preparation and processing. It serves a diverse range of functions in food production, including cleaning, sanitation, and manufacturing. Besides being an ingredient in various food products, water finds application in numerous other operations such as irrigation, transportation, washing, brining, ice production, and plays a vital role in maintaining sanitation and hygiene standards (Bhagwat, 2019). Agricultural water pollution is a global issue and is expected to escalate as the world's population expands and the demand for food rises (Evans *et al*., 2019), being recognized as a significant factor posing a risk of contamination to crops (Allende and Monaghan, 2015).

RESEARCH ARTICLE

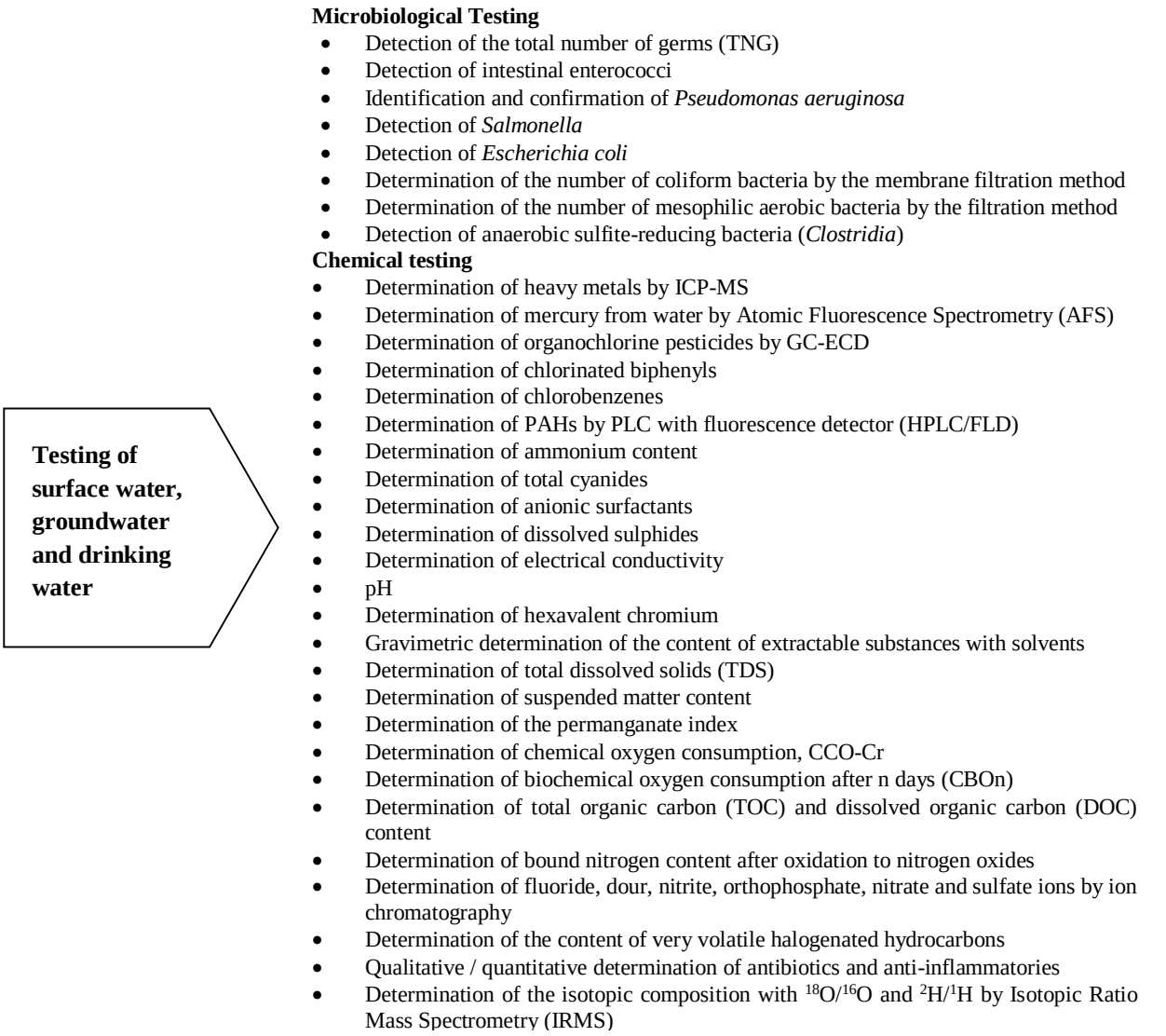


Figure 9. Services offered by METROFOOD-RO for chemical and microbiological analysis of surface water, ground water, drinking water

Water, soil and air pollution not only pose threats to food safety but can also lead to increased health risks. Prolonged exposure to polluted environment can result in severe environmental consequences and health hazards. Contaminants like heavy metals, nitrites, and organic pollutants in water and soil may amplify the potential for cancer and other health-related issues (Lu *et al.*, 2015).

Conclusions

The METROFOOD-RO National Node offers a wide range of analysis services to assess the quality and safety of food products. These services include the detection of chemical, biological,

and microbiological contaminants. Furthermore, METROFOOD-RO provides services for analysing and characterizing food contact materials and food contact articles. Additionally, the infrastructure offers services for evaluating the chemical and microbiological contamination levels in the agrifood environment, including water, soil, and air. The Research Infrastructures of METROFOOD-RO are well-equipped to address the challenges of the agrifood sector and can effectively consolidate diverse capabilities to establish a unified centre of excellence in the domain of Food and Health**.**

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