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Review

The Need for A Multidisciplinary Approach to Face Challenges Related to Food, Health, and Sustainability: The Contribution of CRC I-WE

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Abstract: The importance of the impact of the food system not only on human health but also on planet health is gaining growing attention, and there is now an urgent call to action for developing multi-stakeholder strategies able to end poverty and maintain prosperity and health for people and for the planet. To provide a better understanding of the complex relationships between food, well-being and environment, it is pivotal to generate multidisciplinary knowledge on the promotion of human well-being in relation to multiple interconnected factors such as diet and nutrition, environment, economic, social, and legal aspects. Based on these premises, the present paper aims at describing the proposed role of the Joint Research Center "Innovation for Well-Being and Environment" (CRC I-WE) that was brought to light in 2019 with a strong interdisciplinary nature at the University of Milan, Italy. In 2021, the Center hosted its first annual conference aimed at identifying case studies from the food, health, and sustainability fields particularly deserving an interdisciplinary approach, and which may provide the basis for opening a wider discussion with the scientific community.

Keywords: innovation; well-being; planet health; human health; food safety; novel foods; food law

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1. Introduction

The complex interconnection of factors affecting human health, including a large number of dietary features (both positive and negative), is clearly underlined by a wide range of studies.

The important impact of the food system on the planet's health is gaining attention, as the food system represents one of the main causes of resource depletion and unacceptable environmental impacts, being for instance responsible for about one third of global gas

emissions [1]. This scenario will only worsen if we consider that the global population will grow to over nine billion people in less than 30 years, which will lead to a greater need for food and, therefore, food production, which could have a large impact on climate change and lead to further warming, as shown by projections for 2050 made by the EAT-Lancet commission [2].

Therefore, there is an urgent need to develop multi-stakeholder strategies that can end poverty and maintain prosperity and health for both people and the planet. Against this background, in 2015, the UN Summit developed the 17 Sustainable Development Goals (SDGs) as global objectives to be achieved by 2030, and they present a shared blueprint for peace and prosperity for people and the planet, now and in the future [3]. Among them, there are objectives to end poverty and hunger, ensure well-being, ensure the availability of water, ensure sustainable consumption and production patterns, and take urgent action to combat climate change that will impact nutrition through decreasing food quantity, biodiversity, and food nutritional content [4].

Many SDGs are integrated with each other and cover different subjects—for instance, ending poverty and other deprivations is strictly connected with strategies that improve health and education and reduce inequality—all while tackling climate change and working to preserve oceans and forests. Given this clear inter-connection among SDGs, there is a clear demand for interdisciplinary strategies to find solutions to achieve these goals. We are aware that rules and strategies implementing the SDGs' values must be customised for each different context; otherwise, these values will be confined to abstract ideals, lost in the complexity of societies and their institutional apparatuses. Nonetheless, there is no doubt that the Agenda 2030's implementation can only stem from a multidimensional teamwork.

Besides this concept, there is a growing awareness that human health is closely linked to the health of animals and the environment. This has led to the coining of the term "one health" to emphasise the interconnections between these factors and to highlight the need to include several subjects such as antimicrobial resistance, food safety and food security, vector-borne diseases, environmental contamination, and other threats shared by people, animals, and the environment.

In this context, it is pivotal to generate integrated and multidisciplinary knowledge related to the promotion of human well-being considering multiple interconnected factors such as diet and nutrition, the environment, economics, and social and legal factors.

Based on these premises, the present paper aims at describing the proposed role of the Joint Research Center "Innovation for Well-Being and Environment" (CRC I-WE) that was brought to light in 2019 with a strong interdisciplinary nature. In 2021, the CRC I-WE hosted its first annual conference aimed at identifying case studies in the food, health, and sustainability fields, which are particularly deserving of an interdisciplinary approach. Prominent experts on different subjects presented their research themes, highlighting open challenges and issues that a multidisciplinary approach could help address.

2. The Joint Research Center's "Innovation for Well-Being and the Environment" (CRC I-WE)

The CRC I-WE is headed by professors and researchers, specialised in various scientific, technical, and juridical subjects, from different departments of the Università degli Studi di Milano. This high-profile working group aims at addressing the planet's most pressing environmental challenges from multiple perspectives since, in recent years, it has become clear that an integrated understanding of social and environmental issues is essential to provide a better understanding of the complex relationships between food, well-being, and the environment.

The Center provides a "control room" that is open to other Italian and international institutions, researchers, and UNESCO chairs and will assume a connecting role among experts in legal, biological, chemical, agricultural, and environmental matters in order to promote not only technological but also regulatory innovation and public policies in the fields of public health, food, and sustainable development.

The issues taken into consideration to understand the complex nature of these problems and the ways in which different contributions can offer a more complete understanding will have universal impacts. For example, the Center considers human rights, climate and environmental changes, health and big data, diet and nutrition (including health, legal, and market issues), the application of mass spectrometry to behaviour (the relationship between behaviour and pollution), genetically modified organisms (GMOs), and access to water.

The Center explores topics that confront different scientific approaches in the hopes that a multidisciplinary approach might help identify a possible synthetic indicator—not exclusively of an economic, technical, or scientific nature, but also with a preventive regulatory function.

Moreover, the CRC I-WE aims to promote discussions and research regarding the distribution of food, logistics, and all other steps of the process that have an impact on the planet's well-being. Indeed, some aims of the Center are to discuss how we can provide education to the final consumer, raise awareness, and improve comprehension of the food system.

The performance of the activities carried out at the CRC I-WE will be measured through specific indicators able to demonstrate how effectively the Center is achieving the objectives. These indicators—we scheduled to achieve by July 2022—include: (i) the publication of three monographs and 20 contributions in national and international journals related to the development of integrated multidisciplinary knowledge related to the promotion of individual and population well-being; (ii) five presentations at congresses involving young researchers; (iii) organisation of congresses, seminars and workshops on the topics listed under point (i); (iv) development of innovative methodologies for food safety, the study of the environment, and the study of the relationships between environmental factors, nutrition, and health; (v) development, implementation, and study of new foods and food supplements, including food industry waste, with increased sustainability.

The following paper is intended to open a wider discussion with the scientific community while also contributing some current research that is being conducted on these topics by CRC members.

3. Areas of Discussion

3.1. Healthy and Sustainable Diets: From Science to Consumers

3.1.1. Human Nutrition: Challenges and Opportunities towards 2030

Meeting nutritional needs is a fundamental right for everyone, but analysis of global scenarios shows that the problem of severe malnutrition still impacts over 820 million people in certain geographical areas of the world (151 million of whom are children). At the same time, there is also a problem of overweight and obesity, which affects more than two billion people and has been studied for years with large investments in research, but without achieving a reversal or real mitigating effect. Again, a significant number of people live in a state of poor nutrition and are deficient in one or more essential micronutrients, which is often associated with unsuitable eating patterns. In this scenario, the Global Burden of Disease shows that 11 million deaths (i.e., 22% of the total) can be attributed to unhealthy food choices [5].

In this framework, there is a clear need to develop and promote healthy and sustainable diets and to find strategies able to foster a transition towards the adoption of diets that are simultaneously able to provide adequate energy and nutrients to humans while also impacting the planet's health as little as possible, as extensively reported by the EAT-Lancet Commission [6] and adapted in specific contexts [7,8]. These aspects are still not widely considered in many food-based dietary guidelines, which quite often consider the health aspects of diet but not those related to environmental health or socioeconomic factors [9].

Clearly, these challenges can be solved only through a coordinated and multidisciplinary approach, taking into account a wide range of aspects belonging to different disciplines that should be considered together to identify possible solutions. Unsurpris-

ingly, all the strategies identified to address the great challenge of food and nutrition security, as provided in the FOOD 2030 documents (the FARM TO FORK strategy and the FAO/WHO document on the principles of sustainable and healthy diets) [10,11], highlight the need for multidisciplinary approaches that are able to positively impact the food system as a whole and promote the implementation of effective food policies.

In this context, trans-national and inter-disciplinary connections seem necessary to fill the critical gaps in knowledge related to the food system under the context of climate change, as recently addressed in the European project SYSTEMIC (an integrated approach to the challenge of sustainable food systems: adaptive and mitigatory strategies to address climate change and malnutrition). The project has been funded by the JPIs (Joint Programming Initiatives), HDHL (Healthy Diet for a Healthy Life), FACCE (Agriculture, Food Security, and Climate Change), and OCEANS (Healthy and Productive Seas and Oceans), which jointly launched a call for a Knowledge Hub on Food and Nutrition Security that addresses an integrated food system perspective. SYSTEMIC (https://systemic-hub.eu/, accessed on 15 November 2021) includes a large number of researchers from 42 research institutions in eight countries with different areas of expertise and involves the participation of some CRC I-WE members. SYSTEMIC will contribute an analysis addressing the impacts of climate change on the nutritional quality and composition of food while also defining standards to achieve food and nutrition security by considering the whole population and vulnerable target groups. The wide range of ongoing activities in the project will clarify what calls to action are needed to fill the gaps in our knowledge on future food system scenarios and advance areas of research that are necessary to develop intervention strategies to cope with the different critical issues.

Another example of ambitious scientific research and innovation involving CRC members is the project MIND FoodS Hub, which promotes a vision of agri-food research as an engine of innovation, development, and social responsibility [12]. The general objective of this group is the creation (in the context of the Milan Innovation District (MIND)) of a hub of infrastructures and skills to develop an innovative concept aimed at the identification, production, and sustainable transformation of vegetable products and derivatives with excellent nutritional profiles, as well as their functional validation (with a farm-to-fork approach). This project aims to impact scientific knowledge as well as consumers and all other stakeholders of the agri-food and related sectors. Promoting food quality within balanced and sustainable diets is an effective tool to reduce environmental impact and prevent chronic diseases, as also recently reported in a scenario analysis showing that adherence to a sustainable healthy diet could prevent up to 19–63% deaths in a 20-year period while reducing greenhouse gas emission and land use up to 50% and 62%, respectively [13]. In addition, the dietary shift could represent an important goal that can create new opportunities, businesses, and innovations (including digitalisation and agri-tech) while reducing environmental impacts and preserving biodiversity.

The groups presented above are examples of projects, but an overall analysis of the large-scale research and discussions being undertaken in Europe and the world on the need for healthy and sustainable diets highlights that the great efforts developed to date should be, as much as possible, integrated and connected to promote the principle of open science and dialogue with other significant ancillary sensitive areas and areas of expertise able to cover the complexity of the system.

3.1.2. Nutritional Information: The Case of Front-of-Pack Labelling

Effective solutions aimed at helping consumers in following a healthy and sustainable diet should consider synergies between science and law. Indeed, scientists generally identify public health issues while experts in law and policy help convert scientific evidence into laws that are likely to change the behaviour of individuals. Among the various synergies between law and science, food legislation is one the most challenging but is necessary to help consumers make conscious and informed food choices and follow sustainable healthy diets. In this regard, according to Regulation (UE) 1169/2011, art. 35 [14] on the

provision of information on food, many European countries have developed proposals for "front-of-pack" (FOP) food labels that integrate the nutritional information provided by mandatory nutritional declarations. The FOPs proposed thus far include "nutrient-specific" labels (e.g., the NutrInform battery and Multiple Traffic Light) and summary labels (e.g., Nutri-Score and Keyhole) and are informative or interpretative [15]. In this scenario, the European Union program "Farm to Fork Strategy", among a broad range of objectives, aims to develop a harmonised front-of-pack label proposal by Q4 2022.

From a legal point of view, the primary aim of this labelling is to promote sustainable food consumption and facilitate a shift towards healthy diets. At the same time, the effects on the internal market should also be taken into consideration. To date, the food and agricultural sector has demonstrated how efficient the internal market can be thanks to a good level of harmonisation between member states' legislation. The relationship between harmonisation and the effects on the single market is addressed in the Final Report "The performance of the Single Market for goods after 25 years", where it is expressed that the food sector is 99.7% harmonised [16]. A fragmented system of FOP schemes within the EU may lead to confusion among consumers or competition issues and constitute a barrier for food business operators. In the process of harmonizing FOPs, EU institutions must find a balance between consumer protection, public health, and economic and cultural national interests.

From a nutritional point of view, it is well known that an excess intake of some components (e.g., energy, salt, and sugar) is associated with increased body weight, which is, in turn, associated with an increased risk of non-communicable diseases [5]. However, there is a strong debate on the opportunities and the effectiveness of introducing these FOPs into food products. One of the main subjects of discussion is related to the appropriateness of designating foods as "healthy" or "unhealthy", which entails the risk of oversimplifying a complex concept and could even yield regrettable unintentional consequences [17,18]. In addition, some of these FOPs (e.g., Nutri-Score) are calculated by taking into account 100 g or millilitres of products (since the objective is to compare among products belonging to the same category) instead of their usual servings, which would likely allow consumers to understand their actual intake of energy and nutrients. Lastly, a debate is also ongoing about whether the role of FOP should be to educate (i.e., to inform consumers about the nutritional characteristics of a product) or to highlight a priori which products should be preferred.

Regardless of the harmonised FOPs that will be developed in the near future, it is plausible to hypothesise that none of these schemes will be sufficient alone in encouraging the consumption of a healthier diet. It is likely that a mix of different strategies and legal tools—including nutritional education—will be needed to obtain effective results.

Moreover, a strong connection between law and science is necessary to develop effective solutions that can help consumers follow a healthier diet and guarantee their right to information while respecting the free movement of food in the internal market. This interaction should be intensified when new food products become available on the market, as consumers (both the overall population and specific target groups) must be informed about the characteristics and potential health benefits of, or issues with, these foods. Thus, a dialogue for better science-based legal instruments should always be the basis of transactions towards a more sustainable food system.

3.2. Food Safety for People and the Environment

3.2.1. Novel foods in Future Scenarios

Food security and the creation of a sustainable agri-food chain are among the most important and complex challenges faced by institutions and governments all over the world [19]. The growing population, increased food consumption and demand, and the scarcity of natural resources represent serious and interrelated issues that call, now more than ever, for a profound re-thinking of national and supranational strategies and policies. Considering the urgent aim of feeding future generations, the promotion of socio-economic

and environmental sustainability in the agri-food sector should be accompanied by the guarantee of a high level of food safety and consumer protection. Innovation and new technologies can thus be considered precious allies.

In this context, the EU Regulation 2015/2283, disciplining novel foods, represents a stimulating case study that involves updating and modifying the previous regulation (258/97) and excluding genetically modified food and feed from its scope of application, as such foodstuffs are specifically disciplined by Regulation 1829/2003 [20]. This Regulation defines "novel" food as food that was not used for human consumption to a significant degree by humans before 15 May 1997 in EU territories and that falls, at the same time, under one of the ten categories explicitly indicated by art. 3, para. 2, of the Regulation [21]. This complex and vast list encompasses not only newly developed and innovative foods or known foods obtained through novel production processes (e.g., cultured meat) but also traditional foods coming from Third Countries, such as exotic fruits and insects, which are habitually consumed in certain parts of the world but are "new" in the European food market [22]. These foods could significantly support more sustainable diets, e.g., through new food production techniques that waste fewer natural resources or through the promotion of different and more sustainable protein sources, such as insect-based products [23–26]. This list also includes healthier innovative foods able to, e.g., ameliorate food intolerances and allergies. Consider all these factors, the EU legislator had to determine a correct balance between the promotion of sustainability [27] and innovation in the agri-food sector and food safety and consumer protection [28,29]. For this reason, the EU Novel Food Regulation established a centralised pre-market approval procedure that will be necessary to obtain EU marketing authorisation based on a scientific risk assessment conducted by the EFSA.

Notwithstanding the improvements introduced in the new Regulation [30], some issues remain, underscoring the difficulty in determining a correct balance between different needs and objectives [31]. For example, the long authorisation procedure, together with the expensive studies required to present an application risk, present an obstacle to innovation. Moreover, some doubts and difficulties have been cast on the scope of application covered by the regulation and the novel food definitions provided [32]. Facing these issues, legislators and policy makers must establish a strong and clear dialogue with scientists and economists to guarantee regulatory solutions able to maintain the rapid pace of scientific and technological progress while ensuring food safety [33].

Novel foods will play a progressively more central role in the EU agri-food market, and food producers are increasingly interested in innovative solutions and products. Thus, interdisciplinary dialogue between policy makers, legislators, food safety national authorities, scientists, food safety experts, and economists studying the impacts of new products on the EU market will be of fundamental importance to ensure a high level of consumer protection while prompting innovative solutions to urgent global challenges [34].

3.2.2. The Case of Allergic and Intolerant Consumers

Food safety is based on the ability to guarantee consumers the absence of any molecule that may pose a risk to their health. Food safety is guaranteed by appropriate control plans that monitor possible problems, such as the quality of the raw material, the absence of microbiological contamination, and the absence of contaminants of natural or industrial origin (heavy metals, pesticides, etc.).

For monitoring food quality, food production (HACCP) and self-control plans (ISO standards) have been developed to support producers in risk management. Alongside the directives aimed at protecting the health of the general population, it has become increasingly necessary to outline specific rules to safeguard the health of individuals from specific pathologies associated with nutrition (e.g., food allergies, intolerances, and celiac disease). Diseases associated with food have very different pathogeneses and different foods/molecules that induce reactions in sensitive subjects. Figure 1 shows the main differences characterizing the diseases considered here.

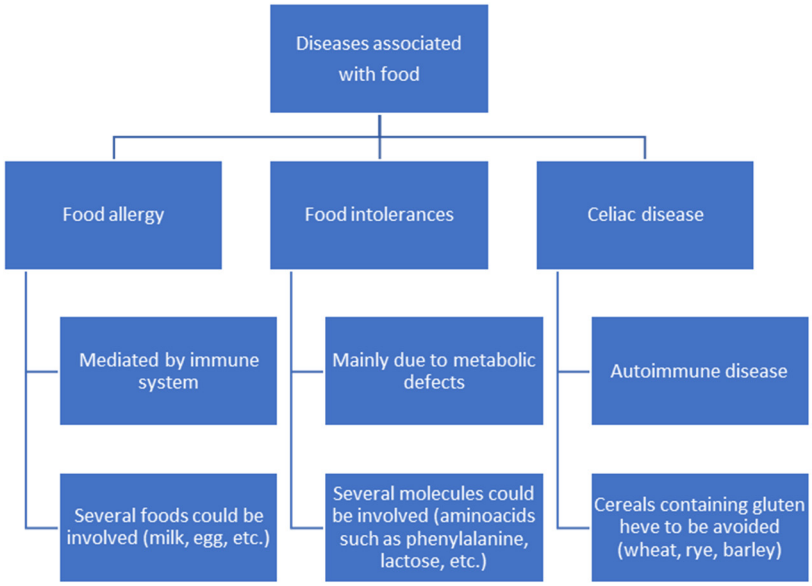

Figure 1. Classification of food-related diseases, their pathogeneses, and the foods/molecules involved.

Differences in pathogenesis and the severity of clinical manifestations of food-related diseases produce different problems in the quality control of food production.

Food allergies, an immune-mediated disease, are overall common, although the number of patients for each specific allergen can be limited. The most common are milk and egg allergies, which appear in childhood and almost always regress within 10 years. The increased frequency of these forms has led to the development of products for allergic children, with particular attention given to the lactation period. These allergies are much less frequent in adulthood (individually), which reduces the interest among companies in producing specific hypo-allergenic foods, as each food would have too small a market. On the other hand, the problem of "traces" is one of the most critical aspects in food control due to various aspects:

- Clinical manifestations have different severity levels, from problems with itching in the mouth to anaphylactic shock.
- The allergen quantity capable of producing a clinical reaction can vary significantly. In "superallergic" subjects, a few milligrams can trigger a response.
- At present, no clinical threshold of allergens has been internationally recognised, so in most countries, there is no legal limit.

The risk of anaphylaxis clearly makes management of the food chain complex, as it becomes difficult to guarantee the total absence of traces due to unavoidable cross-contamination (e.g., the same plants may be used for different products such as dark chocolate and milk chocolate). Furthermore, any traces of certain allergens must be controlled (listed in European Regulation n. 1169/2011) [14], theoretically for all foods on the market. In the absence of legal limits, and despite the numerous efforts made by companies, an optimal situation for allergic consumers has not yet been reached in this sector.

Even in the case of intolerance, the molecules responsible for pathologies are numerous, and their relative medical strategies differ. Congenital metabolic diseases, such as aminoacidopathies, receive specific medical support, and patients have access to specially designed foods. In addition, these diseases have the following characteristics:

- They have a defined tolerance threshold, and in the case of essential amino acids, it is necessary to provide a defined amount of the "toxic" molecule.
- Dietary restrictions in some cases are less strict after adolescence.
- The clinical manifestations are not acute, unlike, e.g., anaphylactic shock, which makes feeding patients more manageable.

A separate case is represented by lactose intolerance, which is a metabolic situation that occurs in a significant portion of the adult population [35]. Indeed, apart from a very rare congenital form, lactose intolerance appears during adolescence and occurs due to reduced activity of the beta galactosidase (lactase) enzyme.

In the case of celiac disease, a widespread autoimmune form, the component that must be controlled is the protein complex called gluten. The most toxic proteins for celiac patients are gliadin (wheat), secalin (rye), and hordenine (barley). Celiac disease is a frequent issue impacting about 1% of the population in Italy. Thus, many efforts have been made both to better define the pathogenesis and to develop dedicated food products.

Celiac disease has some positive aspects from an industrial point of view:

- A clinical tolerance threshold has been defined (around 10 mg of gluten per day), allowing regulators to establish a legal limit for gluten-free products: 20 mg/kg [36].
- The clinical reactions are not usually immediate and do not compromise the patient's life.
- Celiac subjects are numerous, which has led food organisations to invest in research, producing increasingly satisfactory alternatives for celiac consumers. The existence of a legal limit has also facilitated the development of industrial interest.

The area of interest regarding products intended for groups of consumers with specific food-related diseases appears to be an "island", where efforts are limited to a few researchers and food companies. On the other hand, the needs of these consumers create scenarios in which multidisciplinary contributions are critical. Food technology cannot progress without researchers who study the molecular basis and clinical aspects of these diseases while also collaborating with policy makers to help consumers make proper food choices. In practice, the sector of food allergies and intolerances represents a challenge for the future in which increasingly more skills will converge.

3.2.3. Food Safety and Climate and Environmental Changes

Food safety and climate and environmental changes are "two sides of the same coin", as stressed by the World Health Organisation (WHO) and the European Food Safety Authority (EFSA), which both identified climate change as a driving force behind emerging risks related to food, feed, nutrition, and health. Based on the results of the CLEFSA project, recently published by the EFSA in 2020, climate change and its implications for food safety require complex scientific analysis, given the interconnections between the different research areas and the multidisciplinary nature of climate change effects [37]. Being part of an interdisciplinary centre as the CRC I-WE is, therefore, an important asset for researchers at the Department of Veterinary Medicine (DIMEVET), who address both food safety and climate change through up-to-date technological approaches based on mass spectrometry and omics data integration. Thanks to long-term collaboration with the Institute of Anthon Dohrn in Naples, the researchers were able to characterise, at the molecular level, the effects of the increasing acidification and pollution of the oceans on various marine organisms such as Ciona intestinalis, Sea urchins, and, very recently, the brown algae Sargassum vulgare [38–41]. The same methodological approach was used to study the effects of global warming in collaboration with Università "La Sapienza" (Rome). The impact of thermal variations on the aquatic environment was addressed by studying the influence of short (acute) or long (chronic) exposure to stress temperatures on the nervous systems of adult zebrafish (Danio rerio). The results strongly suggested a significant impact on the cytoarchitecture and energy state of the brain, leading to behavioural and social preference alterations and an increased state of anxiety [42,43]. Overall, research on water pollution and warming will benefit from fruitful collaboration with other groups addressing similar issues in the CRC I-WE.

Qualitative and quantitative high-resolution tandem mass spectrometry is also a strategy for the complex analysis of food safety and quality, enabling the detection of drug residues and metabolites with high specificity and sensitivity and offering retrospective analysis of known and unknown compounds with targeted and untargeted approaches.

Highly explanatory and informative data on the proteomes and metabolomes in matrices of animal origin aimed at fraud prevention and the evaluation of functional modifications in animals treated with drugs or exposed to climate/environmental stress can also be determined by researchers at DIMEVET. It is increasingly evident that technology will serve as a driving force for traceability and transparency. Together, these are the three main pillars for improving food security and quality and must be the foundation for a new legislative system capable of responding to the increasingly sophisticated challenges that characterise the current panorama of food safety and quality. Therefore, the presence of legal experts in the CRC I-WE will be beneficial for research and impacts in the field of food safety.

3.3. The Management of Water Resources

The need for a multidisciplinary approach concerns also the use of water, the so-called "blue gold". The management of water resources across different sectors and perspectives seeks to identify ways in which valuation can be promoted as a tool to help achieve sustainability and promote a new "economic and financial value" that overcomes the capitalist logic of previous decades. Among the other issues, it is essential to identify the most innovative adoption of sustainable and innovative irrigation systems that aim to reduce water dispersion, making water management more efficient and developing innovative projects for the reuse of wastewater.

Worldwide, a challenging debate is open among law scholars on the most appropriate legal regime for water. Some authors—due to its importance for the flourishing of human communities—suggest considering and regulating it as a "common good" [44]. However, many other options are on the ground, depending on how water is considered, i.e., as a commodity, a public good or a private good, or an open access resource [45]

Besides its regulation, water will play a pivotal role in how the world mitigates and adapts to climate change, the protection of biodiversity, the promotion of healthy nutrition, and fairness between generations. Indeed, by preserving and restoring terrestrial, marine, and freshwater resources, upon which the food system depends, we can help decelerate climate change and adapt to its effects in order to protect land, soil, water, air, plant, and animal health and reverse the loss of biodiversity.

As highlighted by the United Nations World Water Development Report [46], climate change has an important and vital impact on the availability, quality, and quantity of water. These impacts threaten the enjoyment of human rights and related human health issues, affecting billions of people. The disruption of water conditions due to climate change is a challenge that must be considered in the sustainable management of water resources, which are already under considerable pressure in many areas of the world. Food security, health, urban and rural settlements, energy production, industrial development, and economic growth all depend on water resources and are, therefore, vulnerable to the impacts of climate change. The current status of water resources highlights the need to improve water resource management. Recognizing, measuring, and expressing water's value are fundamental steps to achieving sustainable and equitable water resource management, as well as the SDGs of the United Nations' 2030 Agenda for Sustainable Development [47].

Under this integral and international perspective, the research projects of the CRC I-WE cannot disregard the themes of the COP26 (decarbonisation, the disclosure of climate risk, the strengthening of financial green instruments, and increasing investments in renewable energy and green technologies) or the Expo 2020 Dubai sustainability themes.

Those who are committed in the promotion of human well-being should be aware of the pivotal need of sustainable water resources management. This is particularly true if we consider how much agriculture production is dependent on water. Improving agriculture's water management is thus essential to a sustainable and productive agro-food sector.

3.4. The Future of Animal Production

Population growth, increasing urbanisation, and rising incomes are predicted to double the demand for, and production of, livestock and foods of animal origin in developing countries over the next few decades. By contrast, in developed countries, demand for livestock products is stagnating, and many production systems are increasing their efficiency and environmental sustainability [48–50]. Sustainability entails the rational use of non-renewable and renewable resources (e.g., energy and raw materials), a lower load on the environment by reducing manure production and the excretion of contaminants by animals (as well as safeguarding animal welfare), and ensuring profitability [49].

However, developing and developed countries both require feed. Animal feed is the most important cost factor in livestock production and represents up to 85% of the farm-gate value of most farm animals [49]. Proper feeding and nutrition are thus key to the efficiency of livestock systems. Today, agriculture and livestock are faced with a wide range of complex challenges. With the diminishing availability of farmland, climate change, and the threat of declining water resources, the goal is to meet the growing demand for food, feed, fibre, fuel, and industrial products using fewer resources [50,51]. These aspects have stimulated feed researchers and producers to look for innovative and alternative ingredients to feed animals. Ex-food, insects, and seaweeds (algae) are considered interesting alternative protein/energy sources for feed [52] and are expected to be increasingly used around the globe as replacements for conventional nutrient sources.

For instance, approximately one-third of all food produced for human consumption worldwide is lost or wasted [49]. The biomass potentially available for the feed sector is thus very high (potentially 7 million tons in the European Union) [33]. At this stage, however, the food recovery hierarchy must be considered, as only ex-food can be reused in animal nutrition under this scheme (Figure 2).

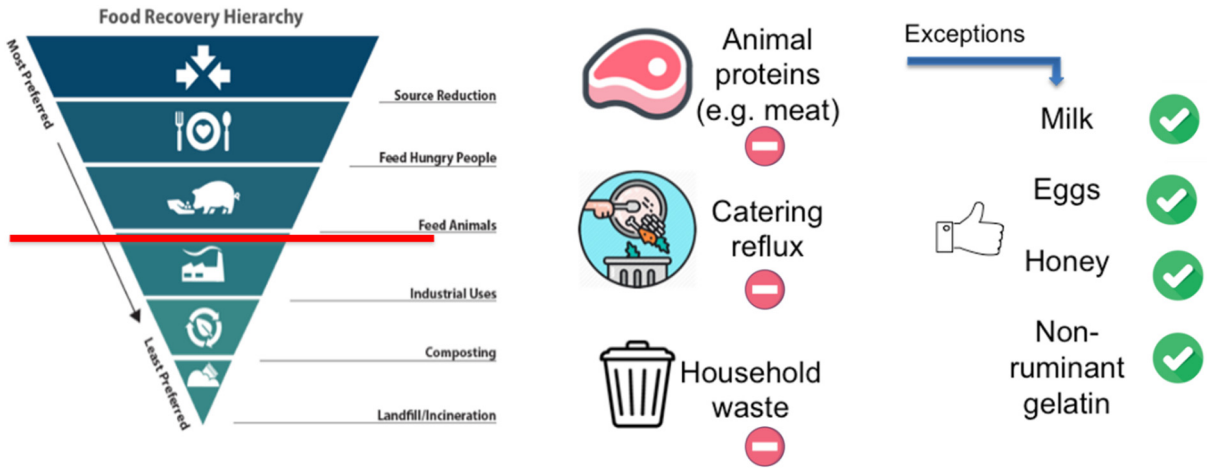

Figure 2. Food recovery hierarchy and former foodstuffs.

Typical ex-foods (also called former foodstuffs) include biscuits, bread, breakfast cereals, chocolate bars, pasta, savoury snacks, and sweets, which all have high energy content in the form of sugars, oils, and starch [53]. The composition of such food varies, and some compositional features (e.g., the content of free sugars) must be studied to ensure that such foods are suitable for animal diets.

Reducing food waste by recycling and enhancing ex-food management can mitigate the environmental impacts and, at the same time, improve economic resources. The use of ex-food for the production of feed matches the aims of the circular economy. If former foodstuffs that are not suitable for human consumption are seen as resources and not as waste products, the food industry can reduce the amount of waste sent to landfills or otherwise disposed of, thus saving costs and reducing the environmental impacts of

the food production chain. This solution requires a close analysis of the components of ex-foods, their safety, and how they can be best exploited in animal diets.

The feed supply chain is a crucial element for all livestock production systems. Moreover, feed supply and feed safety are closely linked. Feed origin, processing, storage, and other factors related to the market can affect, at different levels, the quality and safety of feed. Mycotoxins represent some of the most important safety risks for the feed industry and the security of the feed supply chain [54]. Globally, mycotoxins have a significant impact on human and animal health, economies, and international trade. Despite efforts to control fungal contamination, extensive mycotoxin contamination has been reported to occur in various types of feed and food. In the field of mycotoxin research, a multidisciplinary approach is needed for current and future challenges. Thus, an integrated mycotoxin management system in the feed supply chain and innovative efficient strategies for mycotoxin contamination management must be developed by the feed industry [55,56]. Innovative detection techniques must be developed and validated with a focus on rapid co-contamination detection [57].

Regulation is another critical topic. Mycotoxin regulations are enforced in more than 100 countries, and maximum acceptable limits have been set. However, these limits vary greatly from country to country. The globalisation of the agricultural commodity trade and the lack of legislative harmonisation have opened a wide discussion surrounding the awareness of contaminants entering the feed supply chain [56,58]. Moreover, few mycotoxins are regulated, and information is still lacking regarding the role of modified and emerging mycotoxins, alone or in combination with regulated ones, on animal performance and health. It is, therefore, expected that future mycotoxin regulations will consider these topics and include both modified forms and emerging mycotoxins.

3.5. The Impact of Pollutants and Their Synergy on the Environment

Due to increasingly intensive crop system management and the largescale use of agrochemicals, pollutants, particularly pesticides, are commonplace, especially in the most intensive agricultural areas of western countries, such as Lombardy (northern Italy), which is the richest and most populated part of the country. Unanswered questions surround the possible impacts of synergic exposure to concentrations of pollutants within legal limits on the environment and the potential risks to human health. Considering the framework of the 2030 Agenda, which invites us to study environmental balance with a systemic approach, underlining the strong links between the health of aquatic ecosystems and our individual and collective well-being, an interdisciplinary approach involving the analysis of massive amount of data (Big Data), geolocalisation, integrated models for future prediction, and the use of environmental biosensors could be of crucial importance to monitor not only the state of water pollution but also the sources of emerging risk in order to identify new strategies for intervention, prevention, and changes in production processes. It is, therefore, clear that an interdisciplinary approach is necessary and must involve people working in the area of health, together with lawyers, policy makers, computer scientists, agroecologists, and experts from other disciplines involved in the well-being of animals and the environment. In this framework, the CRC I-WE appears to be strategic. To this end, a recent paper involving researchers from the CRC-I-WE appeared in the journal Scientific Reports and laid the foundations for this approach, indicating that analysing a combination of Big Data and geolocalisation, together with the use of the unicellular alga C. reinhardtii as a biosensor [59], using a rigorous and quantitative approach can provide important results that could be used by lawyers and policy makers to create corrective systems. This interdisciplinary approach revealed not only the areas with the greatest concentrations of pollutants but also that increasing doses of pollutant cocktails stressed the biosensors, which showed the progressive appearance of cell aggregates called palmelloids [59]. Another interesting aspect of this approach is that studying the dynamics of ecosystems at a territorial scale can allow us to investigate the many complex challenges of the great "one health" theme regarding the health of the planet—an area

of innovation that will push us to overcome disciplinary limits to adequately address increasingly complex issues.

4. Ad Interim Conclusion: Next Steps

As the issues in this study show, within the macro-field of food, nutrition, and human health, a variety of specific research lines could be developed through several methods and perspectives. The CRC I-WE's commitment to a multidisciplinary approach aims at allowing a fruitful synergy among different groups of expertise, permitting researchers to place their own knowledge at the service of the others without compromising each other's sectorial rules and peculiarities. This goal is pursuable through various tentative methods based on a dense dialogue between scientists from different disciplines. Such dialogue, however, can hide challenges and pitfalls. Above all, a common language must be found. However, some steps have already be undertaken. For instance, in 2021, at two international events, the Joint Research Center presented a panel named "Let's talk about water in the digital age: a multidisciplinary approach". Events such as these are seeds that should be allowed to grow. This position paper is a call to the scientific community to join such efforts.

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