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BREEDING – NEW TECHNIQUES AND APPLICATIONS

THE NEW APPROACH TO PRIMARY FOOD PRODUCTION AND DISTRIBUTION

FOOD 2030: NUTRITION, CLIMATE

Since the domestication of animals and plants in the Neolithic era, the human race has made efforts to breed new varieties. This can be achieved by traditional selective breeding or by new genome techniques like genetic modification, or by modern new breeding techniques, which allow a faster breeding process.

SPECIFIC RESEARCH AND INNOVATION (R&I) BREAKTHROUGH TOPICS

New varieties of animals and plants: Traditional selective breeding is the process by which humans select specific parent animal or plant individuals to improve particular beneficial characteristics (phenotypes). By improving generations of those specific traits, humanity has achieved the existing species of today. This is a never-ending process, which provides new specifications.

New genetic methodologies and applications: The artificial engineering of the genome of organisms, traditionally known as Genetically Modified Organisms (GMOs), allows the creation of new species by introducing external genome sequences into known species, replacing, or cutting out sequences, thus leading to positive specific characteristics. Modern new breeding techniques (some known as CRISPR-Cas Technology) are not producing what is considered GMOs, instead it allows the introduction of genetic material already existing in the same plant species, allowing for faster selective breeding than would be possible traditionally.

EXPECTED IMPACT

Breeding techniques for animals and plants create species with new characteristics that are beneficial for humans. In the case of plants, varieties with increased drought resistance, higher resilience, pest-resistance, and

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less fertiliser dependency can be produced faster and more efficiently. Some further examples are varieties with increased photosynthesis or seeds and leaves with a modified coating to provide higher resistance to dryer climates. In the case of animals, faster production rates can be obtained in certain species. Overall, it helps tackle great challenges such as climate change and food and nutrition security, or less use of pesticides in plants and antibiotics in animals.

MARKET OPPORTUNITIES / CHALLENGES

- Investments and technology are ready for multiple applications.
- Traditional selective breeding is very time consuming, new genetic methodologies allow for a faster and more reliable process.
- The efficiency and resilience of new plant and animal breeds have to compensate for the possible costs of development and market insertion.
- There is controversy within the scientific community related to the environmental impact of new breeding techniques, mainly in the area of biodiversity and insect displacement.
- Legislation and consumer acceptance might be a barrier for many of the GMO and NPBT applications, affecting labelling issues and detection methods.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Climate change
- Malnutrition
- Scarcity of natural resources
- Agricultural pollution
- Engaged consumers
- Back to nature
- Novel foods
- Biodiversity loss
- Transboundary pests and diseases
- Genome engineering
- Bio-fortification

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Goodberry
- HealthyMinorCereals
- Fishboost
- EggXYt
- Calxyt

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SMART FARMING

THE NEW APPROACH TO PRIMARY FOOD PRODUCTION AND DISTRIBUTION

FOOD 2030: CLIMATE, CIRCULARITY

Modern technology facilitates the potential to increase the quantity and quality of animal and plant production. Smart farming includes a variety of digital tools based on data collection, with the aim of producing more efficiently and sustainably. Some of those tools are worked into sensors, robots, and advanced machinery as well as through applications like the internet of things, data modelling, and artificial intelligence.

SPECIFIC R&I BREAKTHROUGH TOPICS

Precision farming: The management of animal and plant production using near real-time observations and measurements using digital tools is considered precision farming. Examples of these tools include, sensors to follow soil data, irrigation, foliar growth, weed development, and pest management. Overall, these technologies can improve yield output, animal performance, food safety, and reduce farm inputs like fertilisers and pesticides, bringing higher profitability and sustainability to farms.

Use of global data: The data obtained through precision farming can be made globally available through web platforms and forecasts. This data can come from local sensors at farm level, from mobile apps, drone services, and satellites. The data can provide information at a local level, giving smart access to farmers to critical information on farming.

Applied mechatronics: The use of robots and advanced mechanical tools belongs to the field of mechatronics. Examples are advanced drones for data acquisition, autonomous tractors using self-drive technology, and specific autonomous robots for jobs like fruit picking fruit or removing weeds.

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Artificial intelligence applied to agriculture: The intelligence brought to machines is called artificial intelligence. Artificial intelligence allows machines to make decisions based on the acquired data -representing the highest level of crop and animal management in smart farming.

EXPECTED IMPACT

Smart farming has the capacity to provide higher quantity and quality of production, ensured food safety, better traceability, higher efficiency, less fraud, lower costs, improved use of chemicals, and more benefits to a new era of higher sustainability in agriculture.

MARKET OPPORTUNITIES / CHALLENGES

- There is already good availability of these technologies in the market, some of them showing promising technical results, including, higher efficiency and lower environmental footprint from the farm activity.
- These technologies could motivate and attract a specialised workforce, gaining the interest of a younger generation and progression into agriculture.
- Changes to farming practices requires risk management. To achieve success, further support is needed to boost the economic and knowledge transfer factors.
- Often, these technologies are expensive for farmers. Loan and grant mobilisation, public and private funding, co-operative renting, and other economic resources are still a challenge.
- The acquisition of skills for the use of many of these technologies requires the set-up of knowledge transfer, learning tools for adults, vocational skills training, and living labs to make them accessible for all.
- Smart Farming requires interconnection and exchange of data with all benefits and risks involved.
- There is a requirement for infrastructure to support technologies and kit like satellites, data exchange platforms, GPS technologies, etc.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Climate change
- Malnutrition
- Demographic change
- Scarcity of natural resources
- Engaged consumer
- New and Ggme-changing digital technologies in ggriculture
- Changes in farm structures
- Agricultural pollution

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Novifarm
- eFooChain
- CtrlAQUA
- Fhytl Signs
- Flourish
- Prohealth
- Rootwave
- Ida by Connecterra
- AutomonPH by Waterice
- Iron Ox

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NON-CONVENTIONAL PRODUCTION SYSTEMS

THE NEW APPROACH TO PRIMARY FOOD PRODUCTION AND DISTRIBUTION

FOOD 2030: NUTRITION, CLIMATE, CIRCULARITY

After the third agricultural revolution in the 20th century, the mass production of agricultural goods has promoted conventional farming. Non-conventional farming refers to methodologies which use different approaches, from hydroponics to vertical agriculture and urban farming, agroecology, permaculture, and organic production, among others.

SPECIFIC R&I BREAKTHROUGH TOPICS

Hydroponics: Is the art of growing plants without soil, instead using a water solution with the exact amount of nutrients needed. This technology allows the growth of plants without depending on soil and weather conditions.

Vertical agriculture: Also called vertical farming because it uses shelving on which plants are nurtured in a controlled environment.

Intelligent cropping: Includes techniques that use smart management of agricultural concepts like smart crop rotation, reduced tillage, predator pest control or nutrient optimisation.

Agroecology: By definition, agroecology applies ecological principles of environmental sustainability to agriculture. It incorporates a scientific approach as well as a social movement into crop management.

Permaculture: With an emphasis on the ecological aspects of agriculture, it incorporates a social movement and a code of practice. Many associate it with agroecology, although there are slight differences on design and implementation.

Organic awareness: Organic production is characterised by the use of fertilisers with organic origin. It usually merges with techniques of crop rotation and biological pest control. Very often agroecology and organic

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production are inter-related. However, legislation in Europe is very clear in its definition and considerations of organic production, requiring application all along the value chain, including processing.

Urban farming: Urban agriculture is considered within or near-by large urban populations. It includes many different perceptions where hydroponics and vertical farming are also included. But generally speaking, it is perceived as an urban community movement that promotes the value of cropping in urban areas.

EXPECTED IMPACT

Although these new techniques have different methodologies and ideologies, overall they try to bring more environmentally and socially sustainable approaches. Higher quality of crops, better use of resources and land, less intensive use of chemicals, and use of waste streams, all create a greater sustainability within the agricultural ecosystem.

MARKET OPPORTUNITIES / CHALLENGES

- There is a social and ideological aspect to most of these agricultural practices, the market of the obtained products addresses not only economic aspects but also social and environmental issues.
- The associated costs and efficiency of these practices is generally higher than the market standards. However, there are more consumers in Europe willing to pay the extra costs.
- The legislation that applies to the production and labelling of the products, obtained through these practices, can be challenging for new farmers that want to enter the business (e.g. organic production).
- There is the opportunity to develop circular business models in well-defined territorial contexts.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Climate change
- Malnutrition
- Demographic change
- Scarcity of natural resources
- New and game-changing digital technologies in agriculture
- Engaged consumers
- Health and food consciousness
- Changes in farm structures
- Agricultural pollution
- Organic farming
- Indoor cultivation systems
- Urban farming
- Permaculture

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Kipster
- High tech Green House 2020
- Losaeter
- Ballymaloe Cookery School
- Foodmeters
- GrowUp Urban farms
- Herbert
- Micro gardens Dakar
- Soilfood
- Lufa farms
- Infarm
- Bioward Planty Organics
- Nemo's garden
- Seedforward: Freya
- Smart floating farms
- Agrophotovoltaics from Fraunhofer
- Farmers Cut
- Rootwave
- Viro Vet
- Bee flow

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REDUCING THE IMPACT OF PRODUCTION ENHANCERS

THE NEW APPROACH TO PRIMARY FOOD PRODUCTION AND DISTRIBUTION

FOOD 2030: CLIMATE, INNOVATION

Current agricultural production with its use of fertilisers and pesticides in plant production and antibiotics in animal production, has brought challenges through their environmental impact. New approaches are researched to reduce that impact and improve the footprint of production.

SPECIFIC R&I BREAKTHROUGH TOPICS

New approaches to fertilisers: Soil nutrients are usually replenished using non-organic fertilisers. The market for the use of bio-fertilisers is extending, as is the understanding of the soil microbiome, fungi, nematodes, protozoa, and other beneficial organisms to convert unavailable plant nutrients to an available form for plant uptake.

New approaches to pesticides: Crop yield efficiencies are greatly diminished by the effect of parasites, insects, weeds, and other natural organisms. Chemical pesticides are commonly used, but many are considered hazardous for the environment or humans if used in large quantities. New solutions lead to pesticides that have lesser effects against the environment, biodiversity, and human health.

New approaches to animal antibiotics: Livestock farmers use antibiotics to keep animals safe from bacterial infections. However, the excessive use of antibiotics can create antibiotic-resistant bacteria which could be worse for animals and humans. Novel research approaches seek alternatives and new ways to reduce antibiotic use while maintaining animal health.

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EXPECTED IMPACT

Overall, this approach intends to reduce the environmental impact of agricultural production, by using smart alternatives to the current production model with intensive use of chemicals. The expected impact should be a better footprint of production, better use of natural resources, and less environmental damage in rural areas.

MARKET OPPORTUNITIES / CHALLENGES

- There is an increasing market of products produced under these practices. Consumers become increasingly willing to pay more if there are indications of less environmental footprint.
- The solutions provided have to prove of equal or near equal efficiency as the standard solutions to be viable. This is a challenge as usually there are trade-offs in the different provided solutions.
- The process of approval of many of these new solutions might take time, which makes the launch of products to the market difficult for new innovators and entrepreneurs.
- The use of smart technologies can be also used to minimise the input of production enhancers.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Climate change
- Malnutrition
- Scarcity of natural resources
- Agricultural pollution
- Biodiversity loss
- Engaged consumer
- Transboundary pests and diseases
- Alternatives to conventional pesticides
- Changes in farm structures

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Soilfood
- Lufa farms
- Infarm

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NEW VALUE SYSTEMS

THE NEW APPROACH TO PRIMARY FOOD PRODUCTION AND DISTRIBUTION

FOOD 2030: CLIMATE, CIRCULARITY, INNOVATION

Social, environmental, and economic sustainability is being gradually integrated into the agri-food value chain, with a view to implement sustainable business models that can address end users' concerns about the food purchased and consumed.

SPECIFIC R&I BREAKTHROUGH TOPICS

Business models for the primary sector: These models are increasingly seeking to create positive value for a wider group of stakeholders, the environment and society, without compromising profits. Some examples are direct supply chains, added value using principles of ecology, new consumer approaches through joint sales, and distribution co-operatives.

Short food value chains: Chains where food products are identified by and traceable to a farmer, and for which the number of intermediaries between farmer and consumer are minimal. They can be face-to-face, when consumers buy a product directly from the producer/processor (eg on-farm sales, farmers' markets); sales in proximity, when products are produced and retailed in the region of production (eg food co-operatives, specialist retailers, public procurement, catering, supermarkets); or sales at distance, when products are produced outside of the region of purchase (eg PDO, PGI, internet sales, box schemes).

Microcredit and microfinance: Options enabling people to obtain small loans at reasonable interest rates, receive remittances from relatives working abroad, safeguard their savings and set up small businesses. For example, Crowdfunding aims to pool rather small amounts of capital from a large number of people, primarily through fundraising platforms, and has grown in importance as a financing tool.

Social innovation: The assembling of practices that allow agri-food businesses to collect ideas from an external environment that trigger innovation processes and increase their competitiveness, while meeting social needs. For example, the share of agri-food co-operatives in the EU is rising, as they increasingly offer employment

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opportunities and hold substantial market share in industries. Platforms for surplus food recovery and redistribution are spreading in EU countries as well.

EXPECTED IMPACT

New policies and management of the agricultural system can lead towards a new food revolution in the supply chain, and use resources for a more sustainable trade from the primary producer to the final consumer. This will remove margins gained by middle-men and provide a more balanced equity on costs of production. Such new business models have the capacity to re-socialise or re-specialise food, thus allowing consumers to make value-judgments about food. They affect food systems by generating greater employment opportunities, increasing retention of money within the local economy, increasing access to healthy, nutritious, and safe food, and encouraging farmers to adopt more ecologically sound production systems.

MARKET OPPORTUNITIES / CHALLENGES

- Crowdfunding and crowdsourcing provide opportunities for individual investors and consumers to become more directly involved in earlier stages of the food production cycle.
- Short value chains allow for a different consumer engagement where food has added value besides quality and price, such as environmental footprint, regionality or cultural heritage.
- Challenges arise in the current framework for food safety and quality regulations. Often the models followed by the new value systems have difficulties for this adaptation.
- The current distribution system, where big retail supermarkets hold most of the market, puts pressure on gross margins and the final prices that can be achieved, limiting potential consumers.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Trends aligned (with URL)
- Demographic change
- Migration
- Economic globalisation
- Changes in farm structures
- Responsible consumers
- Concentration in food retail markets.
- Short food supply chains
- Chain clustering along the food supply chain

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Kipster
- Be-Farm
- Foodmeters
- Followfish
- Parkslope Food Coop
- Slowfood Europe

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NEW AQUACULTURE

THE NEW APPROACH TO PRIMARY FOOD PRODUCTION AND DISTRIBUTION

FOOD 2030: CLIMATE, CIRCULARITY

Aquaculture is one of the fastest growing food sectors. Innovative systems have been developed to increase its productivity of fish and crustaceans, while reducing the environmental impacts by combining different methodologies. It is a booming sector where technological (breeding systems, vaccines, feeds) and non-technological (market standards, regulatory frameworks, organisational structures) innovation has risen, although challenges still remain for the full exploitation of its capacity.

SPECIFIC R&I BREAKTHROUGH TOPICS

Recirculating aquaculture systems (RAS): This type of advanced fish farm allows an enclosed inland system that recirculates water, reducing the quantity of clean water needed. The main challenge is the elimination of ammonia, often performed through biofiltration, although other solutions exist using aquaponics – the use of natural resources in the trophic chain, like algae.

New feeds: Aquaculture feed production requires fish meal and oil, and products from agriculture as ingredients, these each use large amounts of land, water, and energy. New alternative feeds are being explored to substitute traditional ones, including meals and oils from plants (eg soybean, canola, barley, rice, peas, lupins), fish processing waste, yeast, animal by-products, insect proteins, and seaweed.

Enclosed culture production: This type of system - called cage or pen cultures - enclose the fish, crustacean or molluscs in a wild environment under an enclosed perimeter. This innovation has long been implemented, but with the resolution of its challenges, it can provide higher productivity and better environmental impact.

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Integrated multi-trophic aquaculture (IMTA): Includes organisms from different trophic levels of an ecosystem (eg fish, shellfish, algae), so that the byproducts of one become the inputs of another. It tries to bring the principles of a circular economy into the blue footprint.

EXPECTED IMPACT

There is potential for a better exploitation of seafood resources, from the feeding system to food safety and authenticity. Innovative aquaculture systems such as a closed one - RAS and IMTA - increase production efficiencies, utilise waste water more efficiently, and reduce the amount of required fish feed.

The development of new feeds that are commercially viable as substitutes for fish meal and oil, will enable widespread alternative feeding practices that are successful in reducing dependence on marine fish resources, protecting biodiversity, maximising efficiency, and minimising waste.

MARKET OPPORTUNITIES / CHALLENGES

- The costs for the implementation of advanced aquaculture systems are often high, and entail massive energy consumption as well as dependency on complex technology.
- Wastewater fishponds might play an important role in the future for the recycling of organic wastes.
- The use of insect proteins in aqua feed paves the way to new feed markets for insect producers, feed manufacturers, and seafood farmers.
- There are still technical and social challenges to overcome that require research: From the spread of disease and the impact on environment or productivity to consumer acceptance, lack of specialised workforce or variability in the current regulations in different countries.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Climate change
- Scarcity of natural resources
- Food from the sea
- Closing the loop in aquaculture
- Food waste recovery up-cycling/waste cooking.

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- GrowUp Urban farms
- Agriprotein
- CtrlAQUA
- Climefish
- Nemo's garden
- Smart floating farm
- Fishboost
- Nature Scouts Association (TR)

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THE EMPOWERED CONSUMER

AN ENGAGED AND HEALTHY CONSUMER

FOOD 2030: NUTRITION, INNOVATION

Engagement extends the role of consumers beyond passive purchasers of what supply chains provide, into active and self-organising players who shape the food system and develop solutions based on their values and preferences.

SPECIFIC R&I BREAKTHROUGH TOPICS

Informed consumers and food labelling: The basis for all consumer engagement is information. Mere prices do not reveal information on supply chains, food processing, transport, or ethical issues concerning food. Food labelling can be a crucial vehicle to make visible the social and environmental costs of consumers' daily food choices. Without coherent food labelling it is impossible for consumers to decide if, for example,. a tomato grown locally in a Western European country, but in a glass house with heating and/or cooling, is more environmentally friendly than one transported from a southern country further away.

Active citizenship and education: Food-related education should, on the one hand, start at an early age to be able to impact habits and act as a driver of healthy eating. On the other hand, life-long education and engagement are equally crucial. Food contexts change over people's lifetimes, and novel scientific insights and debates must have a way to reach consumers in order to have an impact on their food choices. However, the form food-related education should take is under scrutiny. At the moment, food-related education is shaped by the senders/tutors, and information gets lost in translation when recipients' requirements and needs are not met. Moreover, schools increasingly take an active role - as exemplified by the City Lab Athens hosted at the Ellinogermaniki Agogi which is pursuing a model of an open school where food project-based learning unites students, parents and the local community - and there are other spaces, agents and roles whose educational potential is still underexplored. Furthermore, there is a chasm between knowing and doing; a richer understanding of the factors influencing people's food choices can complement educational initiatives and help

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them facilitate more sustainable and healthier diets. FIT4FOOD2030 has experimented with developing training based on what recipient communities' own needs are for the transformation of their local food system.

Co-creation and Living Labs: The concept of Living Labs refers both to an organisation and a space where open and collaborative innovation can happen in a real-life context, and through a process of co-creation that includes a diversity of actors. The experience of FIT4FOOD2030's labs at the local and national level has shown that such intermediary structures can be, if designed with care, an appropriate tool for engaging consumers, public authorities, industry and NGOs in value co-creation. Through Living Labs and other forms of participation, citizens can contribute to shape their food system jointly with system stakeholders.

EXPECTED IMPACT

From the perspective of a supply-driven food system, engaged consumers are just one form of input for R&I activities. However, from a societal perspective, empowerment plus consumer engagement should contribute to a food system that is shaped according to the values and preferences of society. A [consumer] value-based food system focusses both on economic and non-economic long-term shared values, like equality and social fairness across the food system, environmental sustainability, clear standards, and animal rights etc.

MARKET OPPORTUNITIES / CHALLENGES

- Market access for novel solutions plays an important role in driving demand. If active consumption means that every consumer has to stand up and dedicate extra time in making (at first) special food choices, then such consumers will remain in the minority. The empowerment of consumers and market access for novel products, often goes hand in hand with disempowerment of established other factors.
- Consumer choices are characterised by trade-offs and tensions between price and other aspects of food production, such as impact on health and sustainability.
- Transparency from farm to fork is important and information should be easily accessible by consumers.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Big data analysis
- Economic globalisation
- Health and food consciousness
- Responsible consumers
- Destabilised consumer trust
- Fast and convenient food
- Changing households and food
- Consumer engagement
- Social media and food
- New shopping behaviour
- Physical internet
- Responsible research and innovation

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Followfish
- Foodintegrity
- Mimica Touch
- Animals' rights
- Bee urban

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No774088

CHANGE OF DIETARY HABITS

AN ENGAGED AND HEALTHY CONSUMER

FOOD 2030: NUTRITION

Poor quality diets are among the top six risk factors contributing to the global burden of disease, mainly through malnutrition and non-communicable diseases (NCDs). The latter is highly linked to poor diets that are high in sodium, low in fruits and vegetables, low in whole grains, nuts, and seeds, and low in omega-3 fatty acids. Innovation in education, policy making, ingredient research, product development, and new insights in consumer behaviour, are some of the leavers to drive this trend.

SPECIFIC R&I BREAKTHROUGH TOPICS

Awareness of healthy habits: Many dietary habits have a social and cultural background. The country we live in, the education we receive, the house economy, the job and lifestyle we have, are just some of the factors that influence our food choices. Awareness is a first step, which requires the understanding of consumer behaviour, but also the methodologies in education, the understanding of transmitted social values, or the existing lifestyle trends. This requires systems in place to deliver this knowledge, adapted to the factual communication channels of citizens.

Reduction of targeted ingredients: There are targeted ingredients that are known to be consumed excessively in unbalanced diets - salt, sugar, and saturated fats - while others lack high fibre foods, whole grains, nuts and seeds, and some vitamins. Efforts are made to reformulate recipes in such a way that the population can change the balance of those components, keeping the taste and price of the usual consumed goods.

Reduction of targeted additives (clean label): There is an effort from the food industry to substitute and reduce certain additives and ingredients from recipes. This is named clean label, which means the elimination from the label of components, often identified with E-numbers in the European legislation. However, this is usually linked with higher transparency on the ingredients (eg allergens) in food labelling.

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EXPECTED IMPACT

The final goal is clear: A healthier population. This involves less non-communicable diseases, healthier growth, and healthier ageing. However, the way we can measure this impact, or the pathways to achieve it, is not clear and more accurate research is needed into the different efforts that are made worldwide.

MARKET OPPORTUNITIES / CHALLENGES

- There is a will from most countries to create awareness towards the issue of unhealthy diets, starting from the efforts of the United Nations, WHO and FAO.
- There are many factors in the research of dietary habits. It requires knowledge of consumer and social behaviour to be able to understand the drivers behind negative dietary habits, which are often linked to lifestyle.
- Lack of awareness is often linked to strong trends such as urbanisation, globalisation or loss of culinary habits, which disconnect society from food sources and the sustainability parameters within.
- The market opportunities get diluted by the lack of homogeneous policies among countries which set different standards and regulatory measures with regard to the ingredients and products to target.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Rise of non-communicable diseases
- Demographic changes
- Biofortification
- High/ultra-processed foods
- Clean eating / transparent labels
- Novel foods
- Natural preservatives and milder processing methods
- Alternative protein sources
- Functional foods including pro and prebiotics
- Health and food consciousness
- Responsible consumers
- Special diets like vegetarian, vegan or low carb
- Destabilised consumer trust
- Fast and convenient food
- Low prices, high calories
- Free-from products
- Smart personalised foods
- Globalisation of diets
- Consumer engagement
- Traditions and do it yourself (DIY)
- Social media and food
- Food regulation

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Baltimore food policy
- KromKrommer
- Alexandra Rose Charity
- Habit
- Doux Matok
- Perfect day
- Geltor
- Sugarlogix
- Miraculex
- Beyond meats
- Clara Foods
- New Wave Foods

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No774088

NEW TOOLS TO IMPROVE NUTRITION AND HEALTH

AN ENGAGED AND HEALTHY CONSUMER

FOOD 2030: NUTRITION

Innovative and high-performance technologies are revolutionising medical research with their ability to assess individual health indicators, and thus allow the examination of multiple human and environmental conditions simultaneously. This is proving powerful in targeting and preventing human diseases more accurately.

SPECIFIC R&I BREAKTHROUGH TOPICS

Personalised nutrition: Personalised nutrition is based on the use of genetic, phenotypic, medical, nutritional, and other relevant information about individuals to deliver specific and targeted advice, products, or services, to achieve a dietary behavioural change proven to be beneficial for health. Consumers are increasingly more proactively involved in the design and production of the food they purchase through co-creation and innovative technologies.

Multi-Omics: Starting from genomics, transcriptomics, proteomics, and metabolomics; a variety of omics subdisciplines (epigenomics, lipidomics, interactomics, metallomics, diseasomics, etc) has emerged, offering the opportunity to understand the flow of information that underlies disease. Foodomics is a new, comprehensive approach to food and nutrition that intends to correlate the intrinsic food characteristics (for example related to food composition, biochemical properties of active ingredients, food processing and technologies used in food production), with the impact on human health.

Nutraceuticals: Nutraceuticals refer to dietary supplements, functional food, medicinal food, and pharmaceuticals. They have attracted considerable interest due to their potential nutritional, safety, and therapeutic effects in improving health, preventing chronic diseases, postponing the aging process, and generally supporting body functions and integrity.

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Functional foods: Functional foods exert specific health benefits on the human body, that extend beyond those associated to nutritional value, improving overall human health status, and reducing the risk of certain diseases. Functional products refer to several categories of foods; conventional foods that are naturally rich in nutrients like vitamins, minerals, antioxidants and heart-healthy fats; food fortified with additional nutrients (eg juices); food enriched with new ingredients (eg pre- and probiotics); or food altered by removing/reducing/replacing particular components.

Human genome knowledge and application: Gut, oral, respiratory, and skin microbiomes play an important role in shaping an individual's response to diet, and have the capacity to rapidly respond to environmental factors like diet, lifestyle, and climate.

EXPECTED IMPACT

Further knowledge of human health - and the tools available to measure and -influence nutrition and healthy eating habits. Indeed, personalisation may foster a sustained change in dietary and purchasing behaviour, and is likely to drive scientific developments which are beneficial for public health. The application of multi-omics technologies, through the adoption of a foodomics approach, integrates multiple levels of research and models, and allows the closure of knowledge gaps and the optimisation of human health.

MARKET OPPORTUNITIES / CHALLENGES

- The market for personalised nutrition is expanding, as it attracts both people suffering from a disease, and healthy people willing to monitor their health parameters. The widespread use of fitness watches and similar applications demonstrates this.
- Market demand for new tools is driven by consumers concerns about health risks. There are perceptions that the pursuit of wellness and a good fitness condition is a top priority, especially for the emerging middle class.
- A foodomics approach to multi-omics technologies can help multi-background researchers and scientists in the area of food science and nutrition to have better access to data. This improve in food safety, new foods formulation, and animal nutrition, and lead to a better understanding of the impacts of environmental exposure.
- Developing microbiome-based dietary interventions can be a cost-effective measure to prevent diet-related diseases and can improve human lifestyle by modulating individual eating behaviours.
- Translating human genome sequencing into medical therapies that will benefit individuals requires strategies to handle large amounts of biological and medical data.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Rise of non-communicable diseases
- Demographic changes
- Biofortification
- High/Ultra processed foods
- Clean eating / transparent labels
- Novel foods
- Functional foods including pro and prebiotics
- Health and food consciousness
- Responsible consumers
- Special diets like vegetarian, vegan or low carb
- Fast and convenient food
- Smart personalised foods
- Globalisation of diets
- Consumer engagement
- Traditions and do it yourself (DIY)
- Social media and food
- Food regulation

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ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- MinorHealthyCereals
- Habit
- Tellspec
- Sugarlogix
- Calxyt

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No774088

NEW METHODS IN EDUCATION

AN ENGAGED AND HEALTHY CONSUMER

FOOD 2030: INNOVATION

From Living Labs to Massive Open Online Courses (MOOCs), and tailor-made webinars to design-sprint hackathons, networks from academia, research, industry, and civil society are developing innovative opportunities to attract, develop and empower individuals to transform food systems of the future.

SPECIFIC R&I BREAKTHROUGH TOPICS

New models for education: The rise of personalised learning models, do-it-yourself opportunities, and interactive learning experiences accounts for the variety of people interested in learning about food systems. Multi-stakeholder platforms and initiatives that bring together higher education institutions, research and training centres, and food companies are increasingly offering cross-disciplinary programmes, including MOOCs, Summer Schools, and dedicated study programmes. Students and professionals can bridge fragmented skills and knowledge of food systems, while future entrepreneurs can learn how to investigate relevant case studies and initiate plans for joint business ventures, supply chain innovation and commercialisation.

Awareness of food systems: These emerging education opportunities focus on empowerment: Raising awareness of the required changes in food systems. They equip key audiences with the knowledge, skills and attitudes to play a role in food systems transformation. Education in food system thinking enables key players to understand the societal, environmental and economic demands arising from different food value chain sectors. It also helps them to identify the full range of intervention strategies available, from technologies and market development to social innovation and adaptive governance regimes. They can also evaluate the interventions and leverage points where there is an established evidence base demonstrating the likely impact of specific actions. Living Labs, linking citizens with policy makers, scientists, industry representatives and civil society organisations, represent innovative examples of a new hybrid format for competence-building in this area.

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Innovation and entrepreneurial behaviour: Education providers are increasingly focusing on closing the gap between scientific expertise in the agri-food sector and business skills relevant to reaching the market, allowing the practical application of research models and the full absorption of disruptive ideas. Dynamic partnerships between scientists and managers are at the core of efforts to catalyse food entrepreneurship - a channel to foster knowledge, innovation, and greater societal engagement. Hackathons, events designed to help aspiring entrepreneurs, find solutions to pressing challenges in the food system and facilitate meeting like-minded peers. These are examples of new methods to promote and accelerate knowledge and innovation transfer between research, business, and public authorities.

Guidance to Start Ups and SMEs, new models of collaboration and impact: New education methods allow agri-food start-ups to benefit from business cccelerators and innovation initiatives, including mentoring programmes held in partnership with established companies, and matching exercises with businesses offering complementary services. Targeted training in innovation capabilities can help SMEs to overcome existing skill gaps and thus unlock untapped market opportunities.

EXPECTED IMPACT

Innovation in education methods will enhance the public's awareness, knowledge, and competences in food systems by reaching a larger and more diverse audience, compared to traditional, mono-disciplinary learning. Empowered citizens will be able to increase the value perception of food and build a more balanced relationship with industry and authorities across the food chain. Professionals in the agri-food business will gain the necessary expertise to develop healthier products and enhance sustainability through resource stewardship. Start-ups will increase their success rates through a better understanding of their market opportunities and improvements in their business plans.

MARKET OPPORTUNITIES / CHALLENGES

- The rise of flexible and distance learning methods in education cross-cuts education domains, producing more products and increasing the competition faced by services focusing on food systems transformation.
- As new education methods often rely on digital literacy and infrastructure, their accessibility is limited to a certain kind of user, which in turn influences the target groups the new learning experiences are designed for.
- The Covid-19 pandemic has provided a strong boost for experimental education methods and has triggered an appetite for learning on food systems and transformative action.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Malnutrition
- Rise on non-communicable diseases
- Demographic change
- Migration
- Scarcity of natural resources
- Rise in energy consumption
- Economic globalisation
- Agricultural pollution
- Biodiversity loss
- Health and food consciousness
- Responsible consumers
- Destabilised consumer trust
- Changing households and food
- Globalisation of diets
- Consumer engagement
- Social media and food
- New shopping behaviour
- Food waste recovery up-cycling/waste cooking
- Women's empowerment
- Responsible research and innovation.

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- BallyMaloe Cookery School
- The Plant

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- Urban gardening with children
- 81 Forests in 81 Cities (TR)

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LOGISTICS – NEW SYSTEMS

THE TOOLS FOR A FUTURE PROOF FOOD SYSTEM

FOOD 2030: CIRCULARITY, INNOVATION

A new way of transporting materials from one place to another globally would change the way we understand trade and the acquisition of goods in a rapid market. New logistical breakthroughs have the potential to contribute to more effective supply chains and circular food systems.

SPECIFIC R&I BREAKTHROUGH TOPICS

The physical internet: The physical internet refers to a radically novel way of managing sustainable logistics which could replace unsustainable and inefficient global practices of how physical objects are moved, stored, supplied, and used. It draws inspiration from the digital internet to create a global logistical network with high interconnectivity, with goods enclosed in smart, eco-friendly modular containers, distributed by multi-segmented intermodal transport. Such a smart but complex global system will be challenging to put in place but has large implications for the logistical dimensions of food systems. It requires technological breakthroughs in infrastructure design, container handling and transportation, and supply chain modes, as well as social innovations that transform the practices involved in, for instance, (online) shopping, food delivery and transportation.

Service 'at the door, at any time': The development that allows consumers to have food delivered to their door at any time is already transforming our logistical practices. It involves the shift towards online shopping and emerging food delivery services, that deliver meals or food directly from farmers or supermarkets to citizens. It has severe impacts on traditional ways of organising catering, restaurants, and retail services. It presents many different challenges and opportunities for rural and urban areas, for new entrepreneurs and more traditional players (restaurant owners, farmers, supermarkets). It has the potential to support local and more sustainable food supply chains and provides opportunities for consumers and businesses. But it raises questions about the position of vulnerable or marginalised communities, and the market position of smaller companies that have to adopt new technologies and practices rapidly to remain competitive.

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EXPECTED IMPACT

New logistical breakthroughs could potentially contribute to the transition towards local supply chains and circular food systems. Such new and high-tech developments could radically change the practices and daily routines of those involved in transportation, catering, retail, restaurants, and food production.

MARKET OPPORTUNITIES / CHALLENGES

- Rapid developments in artificial intelligence and big data analytics provide opportunities to innovate and implement the technological elements of the physical internet. It provides a basis for further development of 'anytime doorstep delivery'.
- Successfully developing the physical internet requires global collective action: Harmonising and transforming legal procedures, contract laws, and protocols, as well as significant investments in renewed infrastructures and technologies, like modular containers, as well as distribution stations and information systems.
- Consumer trends might further enhance the market opportunities for delivery services.
- Radical transformations could be at odds with interests of the incumbent logistics sector and invoke resistance from established players and organisations.
- Breakthroughs in logistics will also affect the way people in the transportation field live and work. They offer entrepreneurial opportunities in an emerging market, but might also negatively affect other people that see their livelihood threatened by such novel practices, like truck drivers and retail workers.
- The Covid-19 pandemic has accelerated developments towards food service delivery, contributing to the capacity of companies (and broader food systems logistics) to transition towards new logistical systems.

EXAMPLE REFERENCES

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- **Urbanisation**
- **Demographic change**
- **Economic globalisation**
- **Changing households and food**
- **Consumer engagement**
- **New shopping behaviour**
- **Physical internet**

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- **eFoodChain**
- **Followfish**

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SMART TRACEABILITY IN THE FOOD SUPPLY CHAIN

THE TOOLS FOR A FUTURE PROOF FOOD SYSTEM

FOOD 2030: CIRCULARITY

In food systems, traceability has become a critical element in supply chain management. It is now considered a new quality index in food. Innovation in the use of information and communication technologies is required to provide transparency and trust through the value chain.

SPECIFIC R&I BREAKTHROUGH TOPICS

Industry 4.0 – Digitalisation in food production: The term Industry 4.0, or the fourth industrial revolution, refers to the use of digital technologies that enable new and more efficient processes, which in some cases yield new goods and services. Digitisation offers enormous potential for all steps in the food supply chain, from food production, packaging and food distribution to nutrition. It enables blockchain technologies to trace the whole food chain, providing information to consumers regarding the origin of food products. Consumers are able to check the nutritional value or allergic risk of products,, as well as other health parameters, to decide on their daily diets.

Blockchain technology for secure food supply: Blockchain technology stores data in blocks, in chronological order. Due to what is considered a mathematical trapdoor, data stored in such a way are impossible to alter or remove. Copies of the chain of blocks - hence the term blockchain - and thereby the information, are distributed among the participants in the network. The copies of the blockchain are then updated when a new block of information is added to the chain.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No774088

EXPECTED IMPACT

Innovations like Blockchain will likely impact the way that food products are sourced, priced, and delivered. It has the potential to monitor social and environmental responsibility, improve provenance information, facilitate mobile payments, credits and financing, as well as decrease transaction fees and facilitate real-time management of supply chain transactions, in a secure and trustworthy way. Indeed, quick tracing of food products to their source will enhance food authenticity, transparency, and trust.

MARKET OPPORTUNITIES / CHALLENGES

- The available data creates opportunities for developing products and services based on intelligence. For example, data can be used in predictive models to predict demand and/or success of a product by making use of new insights about correlations and causalities. As a result, business models can change from responsive to risk-based and predictive.

- New business models will emerge with a wider use of smart traceability technologies. Blockchain solutions can reduce market inefficiencies to create more value. Many inherent inefficiencies, like food waste, are considered a cost of doing business, but blockchain solutions can reduce total industry costs and create new sources of value. New market entrants could offer freshness management services, and product-buyer matching. These new business models enabled by blockchain, can potentially connect the grocery value chain to a new and digitally defined industry-performance standard.

- A main challenge to wider implementation of smart traceability technologies like blockchain remains the complexity of food systems. For a typical agricultural production site, implementing blockchain technology requires a customised system and streamlined practices for data entry. Agricultural products have various forms, storage methods, handling processes, and a variety of data recording methods. Implementing blockchain in scale requires a great effort of customisation with financial and human resources.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Economic globalisation
- Blockchain technology for secure food supply chain
- Destabilised consumer trust
- Concentration in food retail markets
- Food regulation

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- eFoodchain
- followfish
- FOODINTEGRITY
- FreshStrips
- Tellspec

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No774088

A NOVEL APPROACH TO BIOTECHNOLOGY

THE TOOLS FOR A FUTURE PROOF FOOD SYSTEM

FOOD 2030: NUTRITION, CIRCULARITY, INNOVATION

Providing adequate nourishment to the growing world population is one of the greatest challenges of this century. As a result, more research is being dedicated to achieving global food security through common and new tools and technologies. This brings co-benefits to address challenges in climate change and food safety issues. The development of biotechnological tools on the knowledge of genome, its sequencing and modification, opens the possibility of new applications and implementations.

SPECIFIC R&I BREAKTHROUGH TOPICS

Current agricultural practices cannot cope with the increasing demand for food production. Innovative solutions are required to increase productivity and nutritional quality, while ensuring sustainability and environmentally friendly methods. Advancements in food biotechnology, such as genetic engineering and sequencing, and microbiome research and application, have allowed big steps forward. The multidisciplinary field of synthetic biology has the potential to deliver novel agri-food applications. The EU defines synthetic biology as the application of science, technology, and engineering to facilitate and accelerate the design, manufacture and/or modification of genetic materials in living organisms (European Commission, 2014). Synthetic biology uses all available technologies for genetic modification, in combination with mathematical modelling and simulation, but in particular aims at faster and easier processes. Both microbiome and synthetic biology research have emerged and become successful from the convergence of multiple disciplines.

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EXPECTED IMPACT

Microbiomes have a key role in human, plant, animal and, ultimately, planetary health. Microbiome technology has the potential to minimise the environmental footprint of food production and sustainably increase the quality and quantity of farm produce with less resource-based inputs, while having a positive influence on human health. Synthetic biology approaches are expected to contribute substantially to improving agricultural productivity, food quality and production, while ideally attaining a sustainable and cost-efficient practice (Roel & Zurbriggen, 2020). Priority objectives of synthetic biology are to improve plant growth, increase crop yield even under difficult conditions like drought, increase nutritional value, reduce fertiliser usage, and enable photoautotrophic production of pharmaceuticals, food ingredients and biofuels.

MARKET OPPORTUNITIES / CHALLENGES

Within the realms of biotechnology, knowledge of microbiome and synthetic biology have enormous potential in our modern world, for a wide spectrum of beneficial applications.

These include;

- Improving food security by quickly engineering resistant plant types
- Bioremediation of polluted or contaminated soil and water
- Provision of secondary metabolites for nutraceutical, pharmaceutical and industrial purposes
- Use genome engineering to increase the impact of food on microbes
- Increase human, animal, plant and soil health by microbial engineering and beneficial microbe selection.

Risk issues have been raised in relation to human health, socioeconomic and ethical impacts - especially when genome engineering is applied. Public concerns address the uncertainties associated with the long-term impacts on health and environment, including increased allergenicity, as has been the case with genetically modified microorganisms and other novel foods. Novel applications may negatively impact existing supply chains, affecting, for example, traditional producers of plants used for drug supply. Bioethical concerns have been raised together with the potential for misuse of a technology, implying bioterrorism or bioterror.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Malnutrition
- Scarcity of natural resources
- Genome engineering
- Novel food
- Natural preservatives and milder processing methods
- Alternative protein sources
- Functional foods including pro and prebiotics.
- Free from products
- Food waste recovery up-cycling/waste cooking.

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Mosa meat
- Impossible foods
- Ecofeed
- Perfect day
- Geltor
- Toast Ale
- Kiverdi
- Finless foods
- Sugarlogix
- MiraculeX
- Memphys Meats
- Clara food

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INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) APPLIED TO FOOD SYSTEMS

THE TOOLS FOR A FUTURE PROOF FOOD SYSTEM

FOOD 2030: INNOVATION

The 21st Century is living the advent of a digital revolution. The spread of mobiles and similar portable technologies, mobile applications, and easy access to the internet, are changing social behaviour at a very fast pace. This is also affecting the food system rapidly, where new applications and implementations are being developed in several areas. These include new sensors, internet of things, big data, Industry 4.0, robotics, augmented reality, digital twins, and at the top of the digitalisation concept, artificial intelligence (AI).

SPECIFIC R&I BREAKTHROUGH TOPICS

Full exploitation of big data: Data is the backbone of digitalisation. Therefore much development is needed in the food system to research how data is acquired, stored, processed, analysed and used. But social challenges arise and must be considered; transparency, integrity, ownership and validity of data, and ethics.

Internet of things (IoT): The IoT refers to the interconnectivity between machines and devices. Much of the development in the sector depends on this, which still requires research for full exploitation.

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New sensors applied to multiple applications: Sensors are critical for the acquisition of data. Great developments are being advanced in smaller, resistant, and accurate sensors, the starting point for many digital applications, including biosensors.

Digitalisation of industry: The so-called Industry 4.0 starts by integrating sensor technology, data management, IoT, robotics, digital twins, and artificial technology for a more precise, efficient, and sustainable way of producing. In the food sector, many challenges arise as the source are living materials with many changing parameters, usually controlled by humans.

Robotics: Part of the greatest developments in some food sectors is due to advanced robots. Robots substitute humans in tedious and repetitive jobs, frequently adding precision and speed.

Augmented reality and digital twins: These technologies allow for simulations in almost a real replica of a process. It allows for a better use of resources, smaller timescales for development and better design.

Artificial intelligence (AI): Considered the paramount of digitalisation, it consists of creating algorithms that allow advanced and intelligent machine processes. It is the next step in robotics and mechanisation, allowing for operations that not even humans could achieve.

EXPECTED IMPACT

Applicable to many sectors in the food system, from the efficiency of industrial processes to new business models for interacting with consumers, ICT applications and digitalisation are breaking through in other sectors, but still undergoing development in the agri-food sector. It affects the way food is produced, processed, distributed, and consumed, with an impact that reaches deep into social, economic, and environmental elements.

MARKET OPPORTUNITIES / CHALLENGES

- Many technological advances are provided from other sectors, and much of the effort in the agri-food sector is dependent on the development and implementation of such technologies.
- There is a gap between the current skills and the needed skills for workers to adopt many new digital technologies. The skills gap is both a barrier and an enabler; a barrier to the current workforce and systems in place, but an opportunity to upgrade talents and attract a younger generation.
- There is ongoing investment from the public and private sector in digitalisation, and there is a political will and a social preparedness to adopt many of the incoming innovations.
- Environmental sustainability might also benefit from adoption of digitalisation. Processes become more efficient, there is an optimisation of resource use, and there could be advances at citizen level, such as a more coherent food waste management for example.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Industry 4.0 - Digitisation in food industry
- Big data analysis
- New and game-changing digital technologies in agriculture
- Blockchain technology for secure food supply chain
- Consumer engagement
- Social media and food
- New shopping behaviour
- Physical internet

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Rethink Recourse
- eFoodChain
- Fhytl Signs
- Winnow
- Flourish
- Starling
- Ida by connecterra
- AutomonPH by Waterice
- Iron Ox

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FOOD INDUSTRY 4.0 – NOVEL AND EFFICIENT FOOD PROCESSING

THE TOOLS FOR A FUTURE PROOF FOOD SYSTEM

FOOD 2030: NUTRITION, CIRCULARITY, INNOVATION

New approaches for sourcing, processing and manufacturing systems for foods and food ingredients are constantly on the rise. Several sector-specific technologies are emerging; common goals across this innovation area include reducing environmental impact and increasing nutritional quality while maintaining food safety, and the enjoyable experience of consuming food.

SPECIFIC R&I BREAKTHROUGH TOPICS

Novel and efficient food processing includes all steps from cutting and separation of agro and aqua resources, stabilisation of new food structures and products, meal assembly and home cooking. In all stages, new innovations have been taking place, from cutting technologies (water-beam, laser, ultrasound), fractionation, separation and extraction (dry bio-refineries, membranes, adsorption technologies, electrostatic separation, hypercritical CO2), to structuring (emulgation utilising membranes, microfluidisation, ultrasound), and heating (super-heated steam, microwaves, induction, sous-vide, radio-frequency). Also, non-thermal and mild preservation (electromagnetic energy and pulsed electric fields, high pressure treatment, reverse osmosis, cold plasma), filling (aseptic filling, clean room tech, super cooling), and packaging (see packaging breakthrough).

For illustration, non-thermal and mild preservation technologies, like high pressure treatment, are under development to maintain the fresh-like quality of pasteurised and sterilised food, while also reducing energy input during processing. Dry biorefineries have a potential to separate and valorise the different fractions of resources in the agricultural production environment.

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The processing innovations have also been fuelled by new developments in digitalisation, robotisation and 3D-printing (personalisation, mass production, DIY). Plus, nanotechnologies (new formulations, new applications, novel packaging, novel foods, policies applied), system thinking (low input technologies, feedback and feedforward controls, novel sensing methods, etc). In addition, new ways of producing resources (eg via organic production, agro-ecological principles, urban or coastal farming and so on), consumption practices (eg consumer attitudes towards products and technologies, participatory actions, new food preparation schemes, food cultural heritage, etc).

EXPECTED IMPACT

There have been numerous innovations in food processing technologies recently, many of which are sector specific. In general terms, the food industry 4.0 strives to provide more efficient processes in productivity, energy and water consumption, with innovative processes targeted for a wider variety of foods including traditional foods, for more environmentally sustainable processes. These can be achieved with less waste, products of higher nutritional quality, and targeted meal compositions. In many cases it also implies higher productivity or lower production costs. It should be noted that such considerations should go hand in hand with the notion of maintaining, as much as possible, the naturally rich and diverse quality characteristics of resources, so without artificial interventions or over-dimensioned manufacturing steps.

MARKET OPPORTUNITIES / CHALLENGES

- All processing equipment that requires less inputs and avoids losses supports more eco-friendly manufacturing.
- Highly flexible technologies that can be used for either delocalisation and scaling of processing (in the field, at home), or in reduction of time resources.
- Reverse engineering tools that can be used as starting points for meeting consumers' preferences and needs. Also, new participatory co-creation pathways can be developed to bring producers and consumers closer together.
- Digitalisation of processing and utilisation of artificial intelligence will help people make better environmental choices, steering manufacturing processes, and helping consumers to get insights into food processing. This is a typical cross-sector operation.
- Food fermentation technologies due to increasing insights in microbiology that permit the development of new healthy and sustainable products.
- Revival of artisanal and local food processing schemes that enhance the richness of the European food culture.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Rise in energy consumption
- Industry 4.0 - digitalisation in food production
- Big data analysis
- New technologies in food production
- High/ultra-processed food
- Novel food
- Natural preservatives and milder processing methods
- "Free from" products
- Packaging 4.0

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- Food waste recovery up-cycling/ waste cooking
- Food regulation

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Apeel
- Doux Matok
- Geltor
- Toast Ale
- Kiverdi
- Ecoberries by CoreOrganic

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SUSTAINABLE PACKAGING

THE TOOLS FOR A FUTURE PROOF FOOD SYSTEM

FOOD 2030: CLIMATE, CIRCULARITY

Sustainable packaging optimises the use of recycled and renewable materials to minimise its ecological footprint and environmental impact. It has to be beneficial and safe for consumers, maximise efficiency, minimise waste generation, and meet market criteria for both performance and cost.

SPECIFIC R&I BREAKTHROUGH TOPICS

New materials: Besides polyethylene terephthalate (PET) and polypropylene, chitosan and polyhydroxyalkanoates (PHAs) are being used as polymers to substitute conventional biodegradable plastics for the packaging industry. The so-called intelligent packaging (consisting of materials that monitor food conditions and/or the surrounding environment where food packages are stored) is also gaining relevance in the packaging scenario.

Biodegradable materials: There are fully recyclable plant-based materials available from food side-streams, like sugar cane, maize, corn, mushroom roots, seaweed agar, potato starch, cellulose pulp, palm leaf, and beeswax. In addition, some original innovations are organic packages made from agro-industrial by-products that are re-usable (eg compostable food packages containing seeds to be planted) or even edible (eg packages made of nuts, dried fruits and seeds).

New recycling methods: Some innovations in the field of polymer recycling are solvent extraction, the conversion of plastic into fuel (using mixed polymer waste that is otherwise difficult to recycle) and depolymerisation, where the polymer is broken down into raw materials or useful chemical intermediates. Anaerobic digestion is an innovative form of recycling that decomposes organic material and turns it into energy.

Reduced packaging: Several steps are being made to minimise packaging volume and weight, including product/packaging ratio, removing unnecessary components or layers (eg turning plastic pasta/baked goods bags into recycled paper ones), but without sacrificing product safety. Some of the most innovative packaging

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solutions are the disappearing ones, designed in a way so that products do not need packaging at all, or the box in which they are contained can be water-soluble.

New models in the food system: Design thinking is now emerging in the packaging field to elaborate innovative food packaging systems that minimise resource use while being in harmony with shelf life and distribution conditions, as well as consumer food purchase and consumption behaviour.

EXPECTED IMPACT

Higher sustainability of the food system, less environmental impact, better use of resources and waste streams. More sustainable food packaging can improve food safety by reducing bacterial contamination, prolonging shelf life, ensuring convenience in food distribution and handling.

MARKET OPPORTUNITIES / CHALLENGES

- The spread of e-commerce could place a focus on increased packaging requirements.
- Retailers could require ever-longer shelf lives for food products, which could create more niches for smart sustainable packaging technologies.
- Data protection remains a delicate challenge to be faced where consumer behaviour and purchasing habits are concerned.
- Developing sustainable packaging is a multidisciplinary challenge, integrating the packaging industry, logistics, retailers, and primary producers. Therefore, a systemic and collaborative approach is required to reach the sustainability goal.
- Consumers and society at large may have different and conflicting conceptions of what is considered sustainable in terms of packaging, finding the appropriate trade-off represents a challenge itself.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Scarcity of natural resources
- New shopping behaviour
- Responsible consumers
- Biobased packaging
- Packaging 4.0
- Reduction of plastic packaging
- Packaging and health
- Food waste recovery up-cycling/waste cooking.
- Food regulation

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Mimica Touch
- TIPA
- BeeBee Wraps
- Eco-Kiddles
- NanoPack
- Novell Compatible coffee capsules#
- Skipping Rocks Lab
- SusFoFlex
- YPACK
- Ecoberries by CoreOrganic

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DIVERSITY IN THE DIET

THE TOOLS FOR A FUTURE PROOF FOOD SYSTEM

FOOD 2030: NUTRITION, CLIMATE, CIRCULARITY, INNOVATION

One of the key challenges for future food security is meeting the demands for sustainable sourcing of food while a demographic increase is expected. One way to obtain food is to increase the diversity of food sources using new raw materials. Examples of this are new products with high productivity/low environmental impact, like marine sources (algae) and insects. Other ways might be the fermentation of side-streams or cultivating animal cells in a laboratory.

SPECIFIC R&I BREAKTHROUGH TOPICS

New sources not fully exploited: There are diverse varieties of animal, plant and fungi species which are not fully exploited. One example could be the use of legumes, which some cultures use in their daily diets. There is still space for full exploitation of such already available sources. Also, food production and processing produces large quantities of unused side-streams which frequently end up composted or combusted. Those could be converted to food using fermentation processes, incorporating biotechnology, novel fungi, food bacteria and yeasts, or using refining processes.

Full exploitation of marine resources: The sea provides algae, seaweed and krill which are produced in abundance with a low impact on the environment. Harvesting those resources in a controlled manner and educating consumers to encourage acceptance of many of these resources could provide new raw materials with a low environmental impact.

Full exploitation of insects: The non-cordate phyla of arthropods, which includes insects, crustaceans, myriapods, and others, are a good source of protein. They provide very fast protein production under supposedly low environmental costs. Although used by some cultures, they are not mainstream. Consumer acceptance, environmental impact, and food safety are still challenging in this research.

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Cultured meat and cellular aquaculture: Cultured meat is the name of laboratory meat, or in-vitro cell culture. Animal cells are replicated through a laboratory process. Theoretically, there is less environmental impact and no issues of animal welfare. Large investments are already ongoing in those technologies, but consumer acceptance and sustainability parameters are still under research.

EXPECTED IMPACT

Exploring new raw materials allows for a higher diversity in the use of resources and technological applications, as well as an improved health impact on consumers. Lower level organisms can provide higher efficiency in food production, while reducing the use of higher-level organisms that contribute largely to water and land use, and loss of biodiversity. The use of side-streams increases the efficiency of the food chain. Additionally, research into new raw materials opens a new market to consumers, new nutrients to explore, provides new sources of jobs and an increase in the resilience of the food system towards food security. It also provides diversity in consumer diets, offering ground for healthier diets as well as increased food security.

MARKET OPPORTUNITIES / CHALLENGES

- Exploring new resources provides resilience to the food system.
- Often, some of these new raw materials provide less environmental burden through production and processing, reducing the environmental footprint.
- Opportunity for new markets and business models but could replace other markets (e.g. cultured meat vs cattle production). It could be seen both as an opportunity and a challenge.
- Opens the door to new nutrients and sensorial properties in the diet.
- Consumer acceptance and cultural changes might be a challenge.
- Some of these new raw materials require further research to overcome issues, such as food allergies in insects, efficiency in cultured meat, or legislation and labelling application to the final products.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Malnutrition
- Scarcity of natural resources
- Cultured/in vitro meat
- Novel food
- Alternative protein sources
- Health and food consciousness.
- Special diets like vegetarian, vegan or low carb
- Globalisation of diets
- Food regulation

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Mosa meat
- Entomo farm
- Impossible foods
- Agriprotein
- Allmicroalgae
- Ultima Restaurant
- Perfect day
- Finless foods
- Memphys meats
- Beyond meats
- Clara foods
- New Wave Foods

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THE GLOBAL FOOD ANALYSIS

THE TOOLS FOR A FUTURE PROOF FOOD SYSTEM

FOOD 2030: INNOVATION

The robustness of scientific data is the basis for risk assessment of chemical (toxicological) and microbial contaminants. The rapid expansion of scientific and technological advances could allow faster and more specific methods increasing decision making, while also meeting societal demands for reduced animal testing.

SPECIFIC R&I BREAKTHROUGH TOPICS

Rapid scientific advances allow a new era of food analysis for quality and safety. This is particularly being seen in genomics and epigenetics (the science that deals with the study of genomes and the translation into phenotypes; the expression of genes), and advances in technology, such as analytical equipment (eg spectroscopy), computational toxicology, bioinformatics, and the emergence of big data. This allows the development of:

- Analytical technologies that are rapid, exact, low cost, and non-destructive of samples (eg allergen detectors).
- Methodologies for higher traceability and fraud detection.
- Systems for the identification of potential targets for preservation.
- Better modelling for higher accuracy on the potential shelf-life of products (i.e. increasing food security and reducing food waste).

In addition, it could be aspired to reach societal demand for reducing animal tests in food safety assessments.

EXPECTED IMPACT

The food analysis methodologies applied in Europe are advanced, allowing one of the best food safety and quality systems in the world. Nevertheless, new technologies can launch a new era of rapid, unambiguous, low cost, robust and sustainable food analysis and risk assessment. This can improve the way we process, store,

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transport and consume food, from the traceability of ingredients and rapid detection of allergens, to increasing self-life (reducing food waste) and reducing animal testing in food risk assessment.

MARKET OPPORTUNITIES / CHALLENGES

- Accurate food safety and quality is a must for the development of the UN sustainable development goals and the sustainability of the food system, including food security.
- There is already science and technology available that requires further development and application. Targeted R&I investments and support are needed to achieve the full potential of these new technologies.
- The global differences in the management of food safety and quality is a challenge to overcome. Homogenisation of regulation and availability of resources is needed for a world of international trade.
- Communication of food safety and risk assessment to consumers, social media management, and education is a challenge, but with an opportunity for improvement to gain citizens' trust.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Agricultural pollution
- Transboundary pests and diseases
- Destabilised consumer trust
- Social media and food
- Packaging and health
- Responsible research and innovation
- Food regulation

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Tellspec
- Foodintegrity
- Mimica Touch
- Viro Vet

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CIRCULARITY IN FOOD SYSTEMS

A SUSTAINABLE AND DYNAMIC VALUE-BASED FOOD SYSTEM

FOOD 2030: CIRCULARITY

The shift from linear processing and consumption of products, to a sustainable economy which is regenerative by design, requires disruptive innovation. It will allow reduced fossil fuel use and food waste, enhanced resource use efficiency, and increased recycling with the aim to retain as much value as possible across the food supply chain.

SPECIFIC R&I BREAKTHROUGH TOPICS

Reduced waste: By using innovative technology and AI to measure the scale and incidence of their food waste, aware and organised consumers and food service providers can take action by adjusting levels of purchase, as well as establishing networks of food donations and exchange. Innovative solutions are also crucial to reduce post-harvest food loss and extend the life of fresh products. This may be through the use of sun-powered climatised stocking sites that protect perishable crops, or producing resistant, bio-degradable packages enhancing vegetables' resistance.

New uses of waste: Wilting produce can be used in soups, as well as ripe fruit in fresh smoothies. New techniques allow the conversion of food scraps into organic fertiliser, compostable bioplastics, biofuels, and renewable energy. As landfills run out of space, an increasing number of towns are diverting food waste to compost facilities, using the end product to restore depleted soil.

New recycling business models: An increasing number of start-ups are successfully making a business by converting food waste into renewable energy and other products, through a biological process called anaerobic digestion. Innovative companies are integrating worms and larvae into their economic cycles, so as to produce animal feed and organic fertilisers from waste. Entrepreneurs, in areas like coffee and beer brewing, are adding new services to their core businesses, such as the production of organic mushrooms from coffee grains and energy bars from spent cereals.

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New structure in food systems: Innovative solutions designed at the consumer and producer/processer/retailer levels require an enabling regulatory environment to produce large-scale positive effects. Policies can make use of incentives, regulation, and co-ordination to address the effects of action against food waste on winners and losers. Food waste reduction priorities are also increasingly integrated into cross-sectorial policies, for example through legislation adding food waste to the list of mandatory recyclables.

EXPECTED IMPACT

Circularity holds the potential to change food production, processing, and consumption patterns. In the social domain, circular economies can stimulate growth in high-skilled employment and create jobs in areas where unemployment is high. In the economic domain, it can provide new business investment opportunities and produce a positive impact on GDP. Circularity in food systems can also reduce extraction and use of natural resources, decrease GHG emissions and primary material consumption, reduce land-use, and save fresh water use.

MARKET OPPORTUNITIES / CHALLENGES

- Financial institutions can provide innovative loan packages to smallholder farmers, while the latter can benefit from low interest rates thanks to public incentives.
- Waste management enterprises can expand their activities to incorporate reuse of material into their core business models.
- Lack of infrastructure, expertise and/or collaboration throughout the food chain can hinder absorption of innovative practices at the system level.
- The market share held by circular business models is limited. For example, food start-ups are often confronted with a lack of real market demand in the absence of anti-food waste regulation.
- Status quo biases that are still inherent in investments and consumer behaviour can slow the implementation of circular business models.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Climate change
- Urbanisation
- Demographic change
- Scarcity of natural resources
- Economic globalisation
- Health and food consciousness
- Responsible consumers
- Biobased packaging
- Packaging 4.0
- Reduction of plastic packaging
- Food waste recovery up-cycling/waste cooking.

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Feeding the 5000
- Foodwin project
- GrowUp urban farms
- Rethink Resource
- Ultima Restaurant
- Winnow
- The Plant
- Fareshare
- Ostara
- KromKrommer
- Ecofeed
- Toast Ale
- Smart floating farm
- TIPA
- Eat me (AT)

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EFFICIENT USE OF RESOURCES

A SUSTAINABLE AND DYNAMIC VALUE-BASED FOOD SYSTEM

FOOD 2030: CIRCULARITY

Optimising processes from agricultural input to consumer behaviour is relevant for the overall sustainability of the food system. Such optimisation does not necessarily require further intensification of production, but rather involves significant reconfiguration of many different dominant practices and structures that constitute our food systems.

SPECIFIC R&I BREAKTHROUGH TOPICS

Efficient water use: Global agricultural production currently uses about 70% of the world's fresh water supply. Optimising and transforming the way water is used in food systems requires technological innovations reducing water losses as well as optimising irrigation and food processing, as well as transformative interventions that address water scarcity in vulnerable areas, innovations and interventions that reduce and prevent water pollution, and new farming (management) methods that lead to more resilient soils and production systems, enhancing adaptivity and sustainability of the food-water-energy nexus.

Efficient land use: Increasing demand for food has led to greater pressure on and competition for land. Optimising and balancing land-use activities is a critical topic in the transformation of food systems. Efficient land-use can be achieved through (high-tech) innovations (increasing crop yields, vertical farming) that lead to more efficient production, but don't necessarily require intensification of agricultural practices. Instead, moving away from monocultural production and intensive livestock farming, while increasing crop diversity and implementing new innovative practices that combine land-use functionalities (such as agroecology, conservation agriculture, integrated crop-livestock systems and urban agriculture) might pave the way for transformation towards more local, (bio)diverse and resilient food systems.

Efficient nutrient use: Current nutrition efficiency in food systems is hampered by ineffective and large-scale use of fertilisers (in monocultural production) including the adverse effects of this usage on the environment,

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and large quantities of food waste throughout the value chains. Innovations and interventions are required that enhance nutrient circularity (in particular in nitrogen and phosphorus cycles), improved livestock and manure management, and reduce food waste. Efficient nutrient use could be further enhanced through the transition towards plant-based diets, thereby accommodating more efficient water and land use.

Efficient energy use: More efficient energy use in food systems could be achieved through optimising energy use throughout the entire value chain. This means, for instance, moving towards the use and scaling-up of sustainable and renewable energy sources in food production, but also redesigning and innovating industrial food processing. Furthermore, it requires the optimisation of logistical processes, including experimenting and innovating towards shorter supply chains and local food systems to reduce carbon emissions.

EXPECTED IMPACT

Optimisation of our processes from agricultural input up to consumer behaviour is relevant for the overall sustainability of the food system. The impact on the way we produce, process, distribute and consume food will therefore be very significant, as will the impact on biodiversity, climate change, human health, economies and societies.

MARKET OPPORTUNITIES / CHALLENGES

- Increasing awareness of the need to protect the environment, enhance soil quality, reduce pollution, and restore biodiversity is an opportunity to reconsider current land, water, nutrient and energy use practices.
- (Local) governments are increasingly facilitating experimentation with non-conventional production methods that aim to alter land and water use practices and move towards local supply chains.
- Further optimisation of water use in agricultural production might be technologically challenging.
- Lack of infrastructure, expertise and/or collaboration throughout the food chain can hinder absorption of innovative practices at the system level, while incumbent players and institutions might seriously hinder uptake of radically novel practices.
- More institutional and financial support is needed to engage and facilitate farmers in the uptake and upscaling of novel innovations that might optimise land, water, nutrient and energy use.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Urbanisation
- Scarcity of natural resources
- Rise in energy consumption
- Economic globalisation
- New and game-changing digital technologies in agriculture
- Changes in farm structures
- Agricultural pollution
- Biodiversity loss
- Urban agriculture / urban farming
- Consumer engagement

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Kipster
- High tech Green House 2020
- NoviFarm
- Soilfood
- Recare
- Ostara
- Bioward Planty Organics
- Kiverdi
- Agrophotovoltaics from Fraunhofer
- Farmers cut
- EggXYt
- Beeflow
- Urban Beekeepers (AT)
- Bee urban (SE)

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FOOD FOR SOCIETY

A SUSTAINABLE AND DYNAMIC VALUE-BASED FOOD SYSTEM

FOOD 2030: CIRCULARITY, INNOVATION

Access to safe, nutritious, affordable, and sufficient food is key to providing rural and urban communities with good health, sustainable jobs, and self-fulfilment. To achieve food and nutrition security (FNS), it is necessary to tackle global challenges like population growth, resource scarcity and urbanisation by making food systems sustainable, resilient, diverse, inclusive, and competitive for the benefit of society.

SPECIFIC R&I BREAKTHROUGH TOPICS

Community driven social innovations: Climate change, global trade imbalances and the ensuing food insecurity are affecting specific societal groups differently. Local communities and vulnerable groups are reacting faster to the challenges than other levels of governance. In Europe, communities are fostering social innovation through citizen participation to research, City Labs, and citizen science, as well as agricultural practices like urban cropping, urban keeping, and community-supported agriculture.

Green public procurement: Public authorities are major consumers participating in and shaping market practices and norms in the food system. Green public procurement - focusing on the provision of nutritious and sustainable meals for schools, hospitals, elderly people residences and public administrations' canteens – can help stimulate a critical mass of demand for more sustainable goods and services.

Social entrepreneurship: Many entrepreneurs are adapting their business models to the changing policy landscape and consumers' preferences to reflect an increasing concern for health and social and environmental considerations. Social enterprises focus on food as a public good, instead of solely considering profit, thus incorporating issues like fair trade, reduced waste and fair treatment of labourers into their models.

Awareness of waste in social context: While reducing food waste is of great interest to the vast majority of food systems' stakeholders, Europe is starting to realise the scale of the problem and its economic and environmental

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impacts. Increasing awareness and modifying certain beliefs related to the size of portions, colour and aspect of food is needed to reduce the amount of waste from restaurants, schools and, more significantly, households. Innovative initiatives include communication campaigns aimed at overcoming the stigma of using leftovers in the kitchen; cooking workshops on converting wilted vegetables into soups and smoothies; creation of apps and databases which foster donation of edible fractions to social services or to produce bio-fuels or biopolymers.

Trade and consumption norms: The influence of the advertising industry has long encouraged producers, processers, retailers, and consumers to select or discard food solely upon considerations on its aspect and shape. The urgent shift towards imperfect or less processed food as a more 'natural' option bears potential to gradually push the market to value food for its nutritional properties. The awareness of eco-social and environmental impact is increasingly leading to rethinking trade and consumption norms, thus having a positive effect on citizens' health and wellbeing, as well as the amount of waste produced.

Traditions & Do It Yourself (DIY): Consumers show increasing interest in products that are perceived to align as closely as possible with their own traditional cultures. Reacting to the loss of trust in the food industry, consumers are gradually resorting to DIY as a way to access food which values sustainability, authenticity and ethics, and that satisfies emotional and social needs.

EXPECTED IMPACT

The development, diffusion and use of innovation towards food systems transformation occurs within society and in interaction with social relations, practices, norms, and values. As systemic change invariably produces winners and losers, public authorities will need to ensure that innovation in the food system is environmentally sustainable, as well as socially and economically just and safe, especially with regard to the most vulnerable social groups. This may be achieved by reorganising innovation as a social and collective learning process, with the purpose of co-designing and implementing solutions to common grand challenges and the ultimate objective of improving society through the provision of a fundamental public good such as safe, nutritious and affordable food.

MARKET OPPORTUNITIES / CHALLENGES

- Vested interests across the supply chain and institutional resistance to systemic change may hinder the absorption of social innovations by the single market.
- Structural limitations to Green Public Procurement linked to the small size of public authorities at local and national levels can be overcome by the support of European initiatives.
- While market opportunities exist for social entrepreneurs, innovative start-ups are often driven out of the market by a lack of sufficient demand for their services.
- The rise of home-cooking due to anti-Covid-19 lockdown measures taken by many governments represents an excellent opportunity to mainstream DIY practices and build a more conscious relationship between food production, processing, and consumption.
- Ensuring hygiene and safety of food waste recovery, e.g. when donating edible fractions or in DIY products.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Urbanisation
- Demographic change
- Migration
- Scarcity of natural resources
- Rise in energy consumption
- Economic globalisation
- Urban agriculture / urban farming
- Health and food consciousness
- Responsible consumers
- Destabilised consumer trust
- Consumer engagement
- Traditions and Do It Yourself

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- Social media and food
- Food waste recovery up-cycling / waste cooking
- Women's empowerment

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Feeding the 5000
- Foodwin project
- Losaeter
- Microgardens Dakar
- Fareshare
- Alexandra Rose Charity
- Parkslope Food Coop
- Slowfood Europe

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POLICY (AND MANAGEMENT) WITHIN THE FOOD SYSTEM

A SUSTAINABLE AND DYNAMIC VALUE-BASED FOOD SYSTEM

FOOD 2030: INNOVATION

Research and Innovation breakthroughs might happen within the governance of agri-food related policy and management. Some examples of this are responsible research and innovation, regional policies, impact measurement, networks and knowledge transfer.

SPECIFIC R&I BREAKTHROUGH TOPICS

Applying Responsible Research and Innovation (RRI): The principles of RRI imply that societal stakeholders (researchers, citizens, policy makers, businesses, third sector organisations, etc) work together during the whole research and innovation process to better align both the process and its outcomes with the values, needs and expectations of society. RRI guides researchers and investors as well as other stakeholders (policy, society, industry) in anticipating the implications of their work, including relevant stakeholders upstream, and reflecting and responding to those stakeholders' concerns and expectations. In this way, co-design and co-responsibility for the outcomes of research and innovation can be facilitated, increasing societal uptake and acceptability of research and innovation. While the food systems approach strives to provide a comprehensive understanding of food production, consumption and environmental drivers, it is less well equipped to shed light on the role of stakeholders, knowledge and power in transformation processes and on the divergent impacts of these processes.

Regional aspects of the food system: Solutions to complex challenges in the food system need the active participation of citizens to drive positive change. To achieve this, it is crucial to give citizens the opportunity to design policy interventions. Examples include local food (policy) councils or citizen assemblies (Doherty et al, 2020). Local and regional innovations in food system governance include food (policy) councils or partnerships — also called local food policy groups (Santo, 2019). There is a widely recognised need to step up the alignment

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between research and innovation policies at the European, national, regional, and local levels. For wider impact, additional alignment challenges need to be addressed within the realm of R&I policy (i.e. multiple sectoral and transversal R&I policies), between (multiple) R&I policies and (multiple) sector policies, and between R&I policy & society (i.e. multiple stakeholder values and expectations).

Impact of Research and Innovation: Research is vital to inform new policy that encapsulates societal sustainability through RRI into food systems thinking (eg through mission-oriented innovation systems). This potential relates to supporting policy challenges such as: (1) constructing a resonating policy frame, (ii) formulating policy goals, (iii) involving relevant sectors and levels, (iv) the question of what constitutes optimal policy integration, and (v) designing a consistent mix of policy instruments.

Formulating answers to these challenges will enable policymakers and stakeholders to envision the next steps in cementing integrated food policy (Candel & Pereira 2017). Including RRI perspectives into funding calls and projects refers to research performers and research funders. For researchers, this involves quality criteria for effective integration of RRI perspectives into research and innovation projects. For funders, it involves operationalising RRI as assessment criteria and key performance indicators in (i) the agenda-setting for programs and projects; (ii) the definition of calls and guidance for applicants; (iii) the review process and grant agreements; (iv) monitoring processes and (v) impact evaluation (source).

Improving the R&I network: Changes in government policies call for action to build new partnerships and coalitions around holistic transformation agendas. Broader and deeper stakeholder engagement is necessary, including above mentioned citizen-led initiatives but also business-driven approaches for transformative change – integrated value chains, production, and consumption (eg circularity).

Higher implementation of knowledge: Existing best practices in food system transformation have the potential for scaling up and out.

EXPECTED IMPACT

Increased public-private collaboration will lead to higher implementation of knowledge and better measurements of impact, as well as more integrated and holistic approaches.

MARKET OPPORTUNITIES / CHALLENGES

- Seeking convergence of food systems' sustainability levels, food safety standards, environmental policy scenarios, etc, while taking into account and properly addressing each Member State's specificities, transformation path and starting point.
- Exploring and fostering public-private-partnerships as a promising instrument to support food system convergence.

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ASSOCIATED TRENDS IN FIT4FOOD2030 (URL)

- Industry 4.0 - Digitisation in food production
- Big data analysis
- Novel food

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- Destabilised consumer trust
- Consumer engagement
- Social media and food
- Responsible research and innovation
- Food regulation

ASSOCIATED CASES IN FIT4FOOD2030 (URL)

- Baltimore food policy
- Big Picnic
- Lufa Farms
- Recare
- Starling
- Prohealth
- Roadkill (AT)
- Bybi (DK)

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