Food for Tomorrow's Consumer

Step-changing the innovation power and impact of the European food industry for the benefit of a sustainable society

Strategic Research and Innovation Agenda of the European Technology Platform Food for Life

food for life

July 15th, 2016, 3rd Draft

1. Editorial and Foreword

This Strategic Research and Innovation Agenda for the European Food Industry was produced in a group effort by the members of the European Technology Platform (ETP) ‘Food for Life’. The strategy development was preceded by a significant reorganization of the ETP ‘Food for Life’ that led to a new leadership team being put in place in October of 2015. This team formulated a work plan to develop a new Strategic Research and Innovation Agenda by the autumn of 2016.

To develop the Agenda, five scientific working groups were founded, each consisting of recognized experts from industry, academia and research institutions with a proven scientific track record. The workgroups met for two full day workshops in January and March of 2016 to develop and recommend new actions to be taken to tackle emerging challenges in the food sector. A workshop was held in May of 2016 to further refine the underlying strategy governing the call for action of the new ETP. A further revision was developed by the leadership team in June 2016.

At the time of writing (July 2016), this document is still to be complemented with an Implementation Action Plan (IAP), but contains the consolidated suggestions by the ETP as well as a suggested timeline for action items to be carried out. It contains key research and innovation action propositions that, if implemented in the remaining timeline of Horizon 2020, will make a real difference to the sector.

The ETP is now engaging in a consultation progress with key stakeholders to obtain feedback and revise/append the SRIA document. The goal of these consultations is to set priorities and align these activities with national ones. This in turn will form the basis for the IAP to be developed.

Prof. Dr. Gert Meijer, Chair and **Prof. Dr. Jochen Weiss, Co-Chair**

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2.1.1. Economic Importance

The Food and Drink Industry is the largest manufacturing sector in the European Union (EU) in terms of turnover (> €1.2 trillion), added value (€206 billion) and employment. The sector currently serves as a job provider for an estimated 4.24 million people. It is a major contributor to Europe's economy, ahead of other manufacturing sectors such as the automotive industry. A large number of established food enterprises are present in all Member States and, in each of these, they rank among the top three manufacturing industries in terms of turnover and employment.

The Food and Drink Industry is a highly diversified sector both in terms of product types (sub-sectors) and the dimension of the operators, with some companies having just a few employees and others employing thousands of workers. Today, about 99 out of every 100 food and drink companies in Europe are small and medium sized enterprises (SMEs). SMEs generate about 50% of the Food and Drink Industry turnover, and provide two thirds of the employment of the sector, mostly in rural areas. SMEs are often more flexible than large scale enterprises and are therefore able to react quickly to market changes making them first indicators of potential future developments. Their flexibility also gives rise to them fostering the emergence of new entrepreneurs. Moreover, SMEs can serve as role models in terms of how to efficiently manage resources and implement cost-effective, lean production systems.

Despite the financial crisis of 2007-2008 that led to a substantial economic downturn across the entire EU and brought a number of Member States close to bankruptcy, EU food and drink exports doubled over the past decade to reach a record €91.7 billion in 2014, yielding a positive trade balance of almost €28 billion. Globally, that makes the EU the leading food and drink producer in terms of turnover. Today, more than one quarter of European food and drink products are sold to non-EU countries with export numbers continuing to grow. The EU ships foods and drinks to all global key markets with shares continuing to increase (2015 being an exception with a slight decrease expected due to the imposed trade sanctions on Russia).

Food and drink products represent the second largest expenditure of households totalling an estimated €1,066 billion in 2014. In 2013, the share of household expenditure on food and drink products remained stable compared to previous years and varied from 11% to 32% depending on income levels and household location. Since 2010 though, food manufacturing prices have risen at a lower rate than agricultural prices. Since food manufacturing prices depend on agricultural raw material prices and other input costs, there has been a decline in profit margins driven also by difficulties in raising sales prices. Over the past 5 years, food prices paid by consumers (i.e. retail prices) have grown only little (1 - 1.5% per year) which has contributed to low inflation numbers.

However, a forecast of recent trends of food prices published by the FAO and USDA shows that there are some dramatic changes on the horizon that will likely cause price declines to reverse (Fig. 1). The sector is about to undergo a startling transformation caused by a great variety of different drivers; amongst them the continued growth of the global population, climate change, water scarcity, an increased urbanization, and political instabilities fueled by income inequality as a result of globalization (Fig. 2 and 3). The expected disruption will not leave Europe unscathed, but it also offers opportunities for growth if appropriate decisions are made and actions are taken.

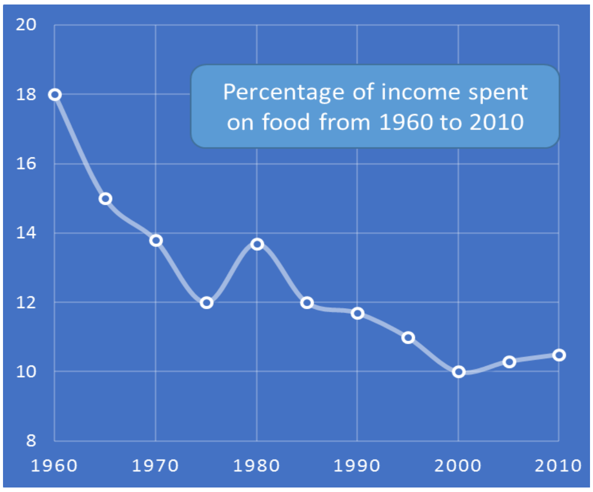


Figure 1. Development of average percentage of household income spent on food from 1960 to 2010. Adapted from USDA ERS [1]

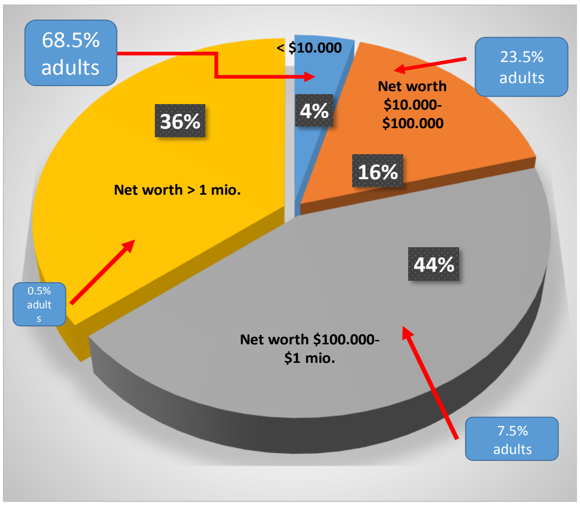


Figure 2. Wealth distribution as a function of percentage of adult population. Adapted from FAO [2].

There is an urgent need for increased private and public investments in research and innovation in order to secure Europe's role as a leading global provider for safe and healthy foods. Europe is better positioned than any other region to do this in a manner that respects and maintains the integrity of ecosystems and environments. The notion of long-term sustainability is deeply anchored in the culturally-diverse European citizenry. It has taken root in local and individual lifestyles, and given rise to an ethical consumerism. Moreover, there is a desire to practice a healthier lifestyle in order to be able to live a more active and fulfilled life. Also, food is seen as a crucial means to achieve this. At a first glance, these changes seem to be somewhat disruptive to established businesses. However, looking into the future, they offer unique opportunities to increase competitiveness and build a more trusted and secure European food supply.

With its new Strategic Research and Innovation Agenda (SRIA), the ***European Technology Platform 'Food for Life'*** looks forward to 2030 and issues a call to decision makers to take immediate actions to improve the global positioning of this important economic sector.

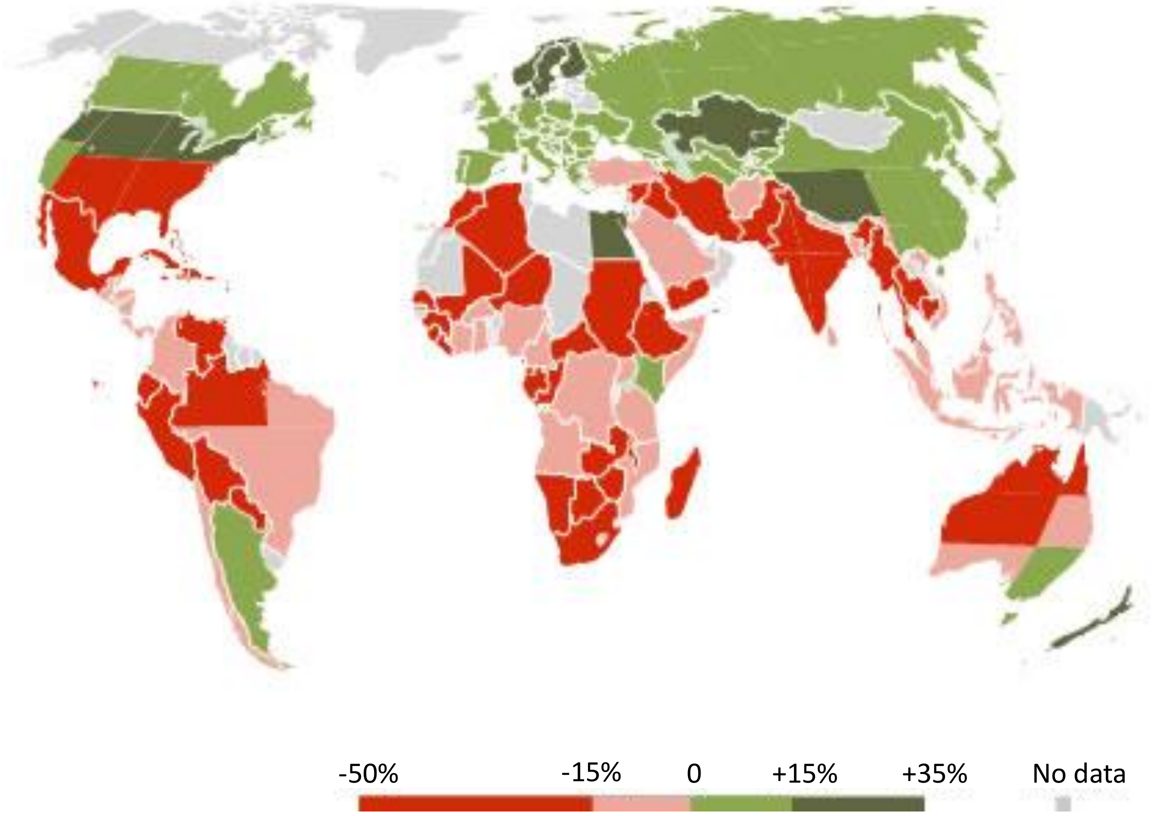


Figure 3. Development of agricultural production by 2050. Areas marked in red will experience a decrease in agricultural yields while areas marked in green will experience an increase. From OECD [3].

2.1.2. Global Position

The European food sector is unique in its very high regional and Pan-European cultural diversity, which is not only a point of pride to many European citizens, but also provides a framework ideally suited to foster creativity and innovations. The great variety of regional culinary traditions that have developed across Europe over the centuries ensure that the work the sector does is deeply embedded in society. The sector profits from a high quality science ecosystem for the food and nutritional disciplines formed by top level industry players, academic and research institutions with a high capacity to carry out ground-breaking research and development activities. Through this industrial and science ecosystem, the sector is supplied with a well-educated workforce that is highly motivated. This is often due its emotional attachment to the subject

“food”. Europe leads in the development of effective regulations to ensure that its food supply is of the highest safety and quality - a distinguishing feature of European foods.

The ability to combine high standards with diverse and interesting food and drink products makes the European food sector competitive and its products very desirable around the world. With a clear focus on health and safety, the European food system is capable of formulating new food solutions ensuring that consumers have access to a balanced diet. Finally, through its diversification, the European food system is able to react and rise to new challenges, which is unlike the case in other, more "food-uniform" regions of the globe.

As of late though, the sector suffers from a substantial lack of consumer trust. There is an increasing perception that its players act somewhat “secretively” and that its activities do not always benefit consumers, but are mostly driven by profit maximization and cost minimization. Moreover, the sector is increasingly thought to create products that do not effectively promote health - and in some cases even contribute to the development of non-communicable diseases. We lack understanding of consumer behaviour and solutions that would support consumers’ lifestyle changes and empower the consumer to make appropriate choices that benefit well-being and health. The development of an unfavourable opinion towards the sector is often amplified by a (social) media environment emphasizing a disconnect between the interests of consumers and the activities of food manufacturers. Social media empowers consumers to communicate with each other in a fast and efficient way regardless of the time and location with all input having an equal status, which often amplifies critical opinions. Instead of turning towards social sciences to develop new ways to better understand the diverse needs and concerns expressed by consumers and involve consumers as active agents in food production, some sector players focus solely on the development of better technical solutions, which consumers will reject, due to the existing lack of trust in the sector.

In turn, the adoption rate of promising new approaches is low because companies fear a backlash. This then leads to low European investments in food system research even though these investments are urgently needed to create new food solutions for consumers. This vicious cycle is further amplified by a lack of access to capital that would fund exploratory and potentially risky ventures, and as a consequence an insufficient number of research results are transformed into innovations. The low degree of innovations then causes value additions to be low resulting in smaller profits, which then again leads to low investments in research and development. As such, the sector is in danger of experiencing a downward spiral that is accelerated by price decays. A lack of new business models in which consumers become an active part of the food supply system and an insufficient integration of players ranging from primary production to retailers similarly contribute to the perceived stagnation. This is exacerbated by an increasing dependence on raw material imports making the sector very vulnerable to commodity price fluctuations. Taken together, the food system is currently under a considerable stress, and Europe risks losing its leading position in food manufacture.

Notwithstanding this somewhat bleak assessment, there are a great number of opportunities on the horizon that could – if realized – help the sector to regain strength and prosper thereby benefiting the European citizenry. In general, the food arena has a tremendous potential for growth. Such growth is fuelled by the continuing growth of the global population and the emergence of new markets with consumers there becoming more affluent. Moreover, food is not just like any other product. It is essential to life and has strong physiological functions influencing health and wellbeing. There is clear evidence that food plays an important role in the prevention and development of non-communicable diseases. Malnutrition occurs both upon over- and under-consumption, and both have severe health effects. Apart from affecting how well we age and how active and healthy we will stay when we get older, food consumption has a strong social function. Eating brings people together and can bridge cultural differences. Shared meals can strengthen family bonds, provide a distraction from work and be relaxing. Furthermore, food is a commodity that is incorporated into our bodies, which makes us very sensitive to uncertainty and unknown elements in food. In other words, food has a strong emotional meaning, which explains the sometimes adverse reaction to technology used to manufacture it. New digital technologies provide completely new ways of linking the consumer to technology and product providers. New food manufacturing approaches are on the horizon that will change the established roles of food producers and consumers. These approaches can allow consumers to experiment and take part in food manufacturing and thus lower the barriers that disconnect today's consumers and producers. This development has also raised the awareness of consumers that food is important and that it is a matter worth focusing on.

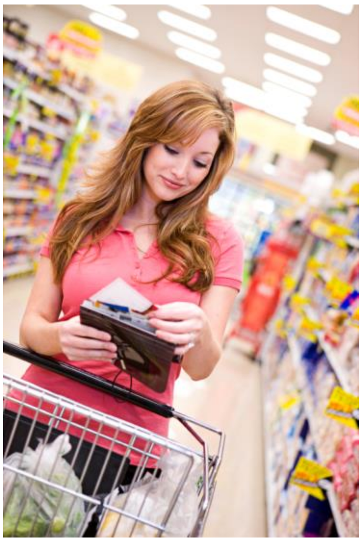
While there are many opportunities that could truly advance the sector and guarantee growth for years to come, there are also large threats that need to be addressed. While a few territories will actually experience agricultural production increases over the next year, many other areas of the world – especially those already suffering from a precarious water supply - are predicted to experience a decline. For Europe that means that imbalances will develop with some regions possibly losing their self-sufficiency in food production. Making the European food system sustainable will therefore increasingly become a challenging task. Access to needed raw materials may become limited, and raw materials may decline in quality, which in turn would make it more difficult to maintain the high standard of quality and safety inherent to European food products. Coupled with an increased income inequality, the number of consumers having access to higher priced food items may further decline. The wealth gap may lead to or turn into a "food gap", and the increasing number of food banks is an early warning sign of that. Continued price volatility may lead to a growing reluctance of investors and existing enterprises to take risks in developing new businesses, new technologies and new products. This would inevitably lead to global competitors overtaking leading European players. On the consumer front, low engagement levels may further lower public trust and acceptance of food solutions. In turn, there is an even higher risk that decisions will be based on opinions rather than on scientific facts. It is not unlikely that consumers will then start looking elsewhere to get their food needs and wants addressed.

2.2. Analysis of Key Challenges That Need to be Addressed

Based on the above presented situation of the sector, there are four global key challenges that the ETP 'Food for Life' has identified as being critical and for which the European food sector needs to develop solutions. The challenges below will need to be tackled by 2030 to ensure that the European food system increases in strength.

2.2.1. Consumer Engagement, Consumer Behaviour and Perception of Food

Surveys show that consumers increasingly distrust the food sector as a provider of food solutions that they want or need. This is not necessarily the fault of the players currently involved. The digital revolution has fundamentally altered the way we interact with each other or with industry and how we approach and perceive new technologies and products. Consumers are now used to having an access to detailed information regardless of time and place. However, food manufacturers are still reluctant to share all information about a particular food product since this could provide competitors with an unwanted advantage. Rather than protecting intellectual property via patents, trade secrets are still widely used in the food industry to maintain a competitive edge. Such trade secrets by their very nature cannot be disclosed. Moreover, consumers are becoming increasingly diverse when it comes to making food purchase decisions due to an increasing number of drivers. Aside from traditional drivers such as price, taste, appearance, new intangible criteria related to health, sustainability, authenticity, ethics, and emotional and social needs play a greater and greater role. Furthermore, based on sustainability and health promotion, consumers are pressurized to change their food-related behaviours, which is difficult as food choices are deeply embedded in our social identity and emotional well-being in addition to habitual and practical barriers. Consumers often wish to make certain changes in the food-related behaviour based for example on nutritional recommendations, but they lack the effort and external support which makes implementing these changes difficult. To date, there is an insufficient understanding how to effectively support the consumers in making these lifestyle changes and which changes can be done by making changes in food availability or distribution models.



Between now and 2020, the sector will need to implement measures to regain the trust of diverse consumers by better understanding and serving their needs and wants. To that purpose, methods have to be devised that allow food manufacturers to communicate more effectively with consumers. Education and disclosure of decision-making facts with respect to the reasons for and the choice of raw materials and processing technologies are needed. A rekindling of the lost appreciation and understanding of the benefits of food processing to create a safe and high quality food supply is needed. Some of this could come from a renewed focus on the exploitation of the cultural diversity of European food traditions. A better collaboration using modern media and new digital technologies in the food arena will need to be put in place. Privacy and data security issues surrounding the ethical use of Big Data for food development purposes need to be addressed. The long-term consequences of short-term marketing efforts need to be better understood and assessed. New, effortless solutions to support consumers' healthy and sustainable food choices and thereby well-being need to be developed.

By 2030, substantial progress must have been made in the communication and interaction with consumers so that technologies that are beneficial for human health and for the environment become accepted. Converting kitchens or supermarkets into massively distributed food development places could lead the way. This would also allow for a personalization and customization of food on a decentralized level. Such approaches could empower the consumer to become part of the food manufacturing system and create a common food ecosystem. In that way, the benefits of technologies for guaranteeing the long-term safety and quality of foods can then be better be aligned with consumer needs and wants.

2.2.2. Demographic Changes

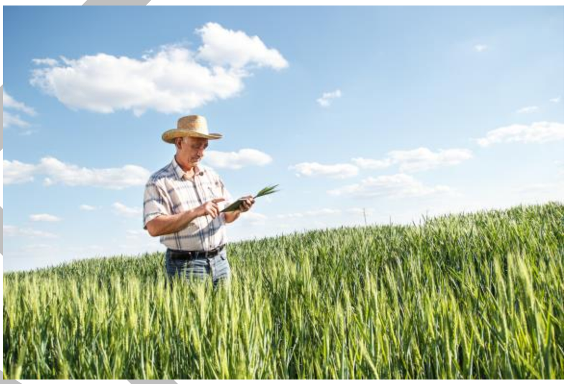
The global population is undergoing a rapid change not only in terms of their number, but also with respect to their composition. Modern medical achievements paired with successes of the food sector have led to tremendous increases in the average lifespan of a person. Data from 186 countries shows that in 1960, the average person was only expected to live for 52 years, while in 2010, this expectancy had gone up to nearly 70 years and it continues to rise. In addition, there is a trend towards urbanization, which is in contrast to most of human history where humankind has lived in rural settings rather than in cities.

Between now and 2020, new food solutions that address a growing but also an ageing global population will need to be developed. Food-specific responses to city growth have to be promoted. Indeed, in 2008, the world's population was for the first time evenly split between living in urban and rural areas. The trend towards urbanization differs from region to region and differences between the developed and the developing world. Differences between Eastern and Western cultural practices, also need to be taken into account.

By 2030, food will need to become affordable but also nutritious and health promoting, which will be a challenge considering the projected demographic changes. While an insufficient caloric intake may decline as a reason for malnutrition, hidden hunger that is the deficiency of specific micronutrients may increase. In addition, it is likely that the divide in wealth may become even greater requiring that affordability and accessibility be considered to a greater extent.

2.2.3. Resources

Even though there are currently sufficient or in some cases even abundant resources available to produce food - a fact that has in turn led to a decrease in undernutrition (and conversely a rise in overnutrition) - this situation will likely not persist for much longer. With the number of natural resources that are gradually being depleted going up and global population continuing to increase, securing a continued supply of high quality raw materials will surely become one of the great challenges of the 21st century. Climate changes cause more extreme weather phenomena. Coupled with a decrease in water availability this will decrease agricultural production in many areas. An increasing competition from other sectors such as the chemical and energy industries will put additional pressure on the food supply system.



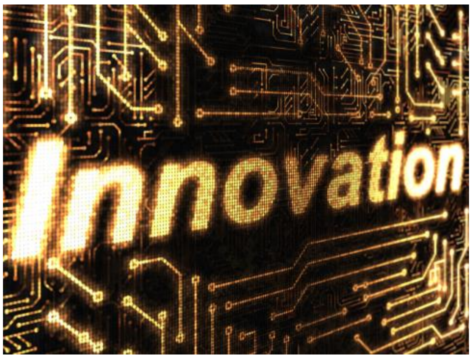
Between now and 2020, the sector will therefore need to find new approaches to become more water and energy efficient, or to become more flexible in their use. New methods and technologies to use resources more holistically will be needed. Moreover, the need for more biological resources must be balanced with environmental protection and sustainability considerations. The effect of the growth of power imbalance and income inequality will have to be taken into account when developing new food systems.

By 2030, flows in the global food system must be fully circular and thus minimize waste along the supply chain. New technologies including the synthesis of food components from non-food materials or the use of non-traditional resources such as insects or microalgae should be fully explored and embraced to supplement the diminishing supply of some raw materials. To overcome the growing divide between the have and the have nots, measures should be taken to develop a shared profit food system.

2.2.4. Sector Maturity

There is a certain 'fatigue' within the sector as a result of its maturity. The industrialization of food manufacture dates back to the beginning of the 19th century following advances in chemistry and metallurgy which gave rise to great productivity increases in agriculture. As a result of a growing raw material supply, there was a need to develop new machinery and technologies to process and preserve agricultural products. As a consequence, food became widely available. This in turn caused prices to decline. Today, households spend not even 10% of their income on food, while in 1900 a family would on average spend about 40% of its entire household income on food. The wide availability of food at low prices has led to it being taken for granted and not sufficiently valued.

Between now and 2020, the sector players will hence need to find new ways to address the low translation of valuable research results into successful innovations. There is a need to



become much more entrepreneurial to answer the upcoming changes in consumer needs and wants. The question of how to align the various stakeholders around the topic "food" so that solutions can be developed that serve European citizen needs must be addressed. A means to revitalize the sector could involve making food again much more diverse and wanted; a practice that has of late led to a revitalization of for example the beer industry (e.g. craft manufacturing and microbreweries). In line with this, new approaches to make food more indispensable need to be developed, e.g. by creating a more non-uniform offering composed of not only low cost but also luxury goods. Here, an integration of recent developments in the culinary arts and in gastronomy into the wider food sector could be a valuable approach.

By 2030, food should become a highly desired product category again, comparable to the fast moving and highly wanted consumer electronics products. To that purpose, food should not just be nourishing, but also be fun and enrich people's lives. This may be accomplished by an increased 'virtualization', that is by transforming it from a purely physical product to a both physical and virtual one. Technologies such as 3D printing have begun to be commercialized and facilitate such changes. There, design concepts can be developed and customized using software approaches. Products are then produced by following those blueprints. While disruptive to established business, this could lead to new enterprises which would make the sector fashionable and pioneering. As a consequence, instead of being driven by developments in other sectors, it could become a look-to and go-to one.

2.3. Our Vision - Create a Better Working European Food System for All

Our ambition.

The ETP 'Food for Life' will foster a thriving European Food Ecosystem that builds on cultural diversity with consumers and industry working in partnership. The Food System of Tomorrow uses nature's resources in a responsible and sustainable manner, is dynamic, flexible, fully transparent and accessible to all. Progress is made by bridging modern social and natural science and technology approaches to benefit the greater public making healthy and sustainable food alternatives not only effortless and affordable to all consumers, but also desirable and exciting.

Our mission.

In consultation with key stakeholders, the ETP 'Food for Life' will develop a pre-competitive research and innovation strategy composed of a targeted set of action items that will serve to holistically address European food system challenges that threaten competitiveness of the sector. It will ensure a proper execution of the plan and verify that its implementation creates a sustainable, healthy, safe and high quality food supply by use of new food manufacture approaches which in turn will create new employment opportunities. Focusing on needs and wants of tomorrows' consumer, it will actively engage with consumers to address malnutrition and the rise in non-communicable diseases, and enhance appreciation of and trust in the European food supply.

2.4. References

[1].

[2].

[3].

3. Step Changing the Innovation Power of the Food Sector - A Call to Action

To make progress towards the formulated vision, the ETP 'Food for Life' proposes a number of targeted research and innovation actions that are described below in detail. The actions are intended to foster a shift from a conventional mass production model to a more personalized and customized one involving and engaging the consumer while simultaneously promoting flexibility and resource efficiency. **Figure 4** shows a schematic overview of the proposed action items along a future-oriented development space that intends to facilitate this fundamental shift. The proposed action items are designed in an integrated way to avoid segmentation or fragmentation of the sector.

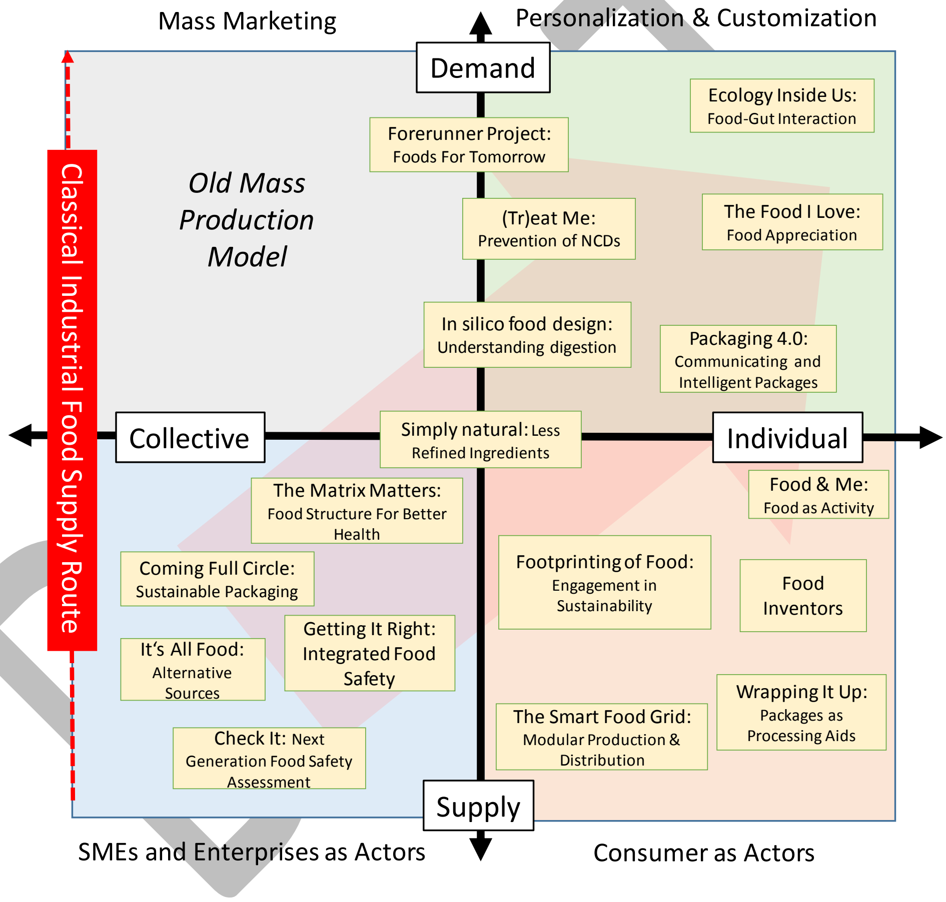


Figure 4. Schematic overview of proposed action items focusing on three research and innovation targets.

A deeper understanding of consumer wants and needs based on modern data generation and analysis will aid to reach three specific research and innovation (R&I) targets:

- **R&I Target 1**: increase the engagement and involvement of consumers
- **R&I Target 2:** create a more personally-relevant and customized food supply
- **R&I Target 3:** develop a more flexible, dynamic and sustainable food system

3.1. R&I Target 1: Increasing the Engagement and Involvement of Consumers

Aim. In the future, consumers should feel that they are not only at the receiving end of the food supply system. They should not be seen simply as purchasers, but as an active part driving the development of a future food supply system. As active players and participants, consumers will have a stake in the game and help make sure that solutions are developed that are not only accepted but also implemented by them. To accomplish this, we need to find new ways to empower and engage consumers to become active.

R&I target 1 aims at achieving this goal by carrying out R&I projects that can help overcome both technological and social hurdles stifling transformation. Five actions have been identified as priority measures to develop a new partnership between consumers and food business fostering the creation of a decentralized food innovation space. Firstly, new and effective communication pathways and methods to better understand consumer wants and needs have to be established. Secondly, new food production and delivery models need to be put in place that can be implemented locally to provide better access to the food system. Thirdly, new methods to allow consumers to better understand and directly contribute to and enhance sustainability of the food system need to be developed. Last but not least new processing and packaging approaches need to be created that are modular and scalable and thus allow for maximal flexibility empowering consumers or small groups to become producers.

Implementation.

Improving Insights into Consumers. A thorough understanding of consumer and societal issues as they pertain to foods is the basis for a rational forward-looking development in the food sector. Today, a myriad of new techniques has become available to accomplish this. These include not only traditional surveys, but involve physiological techniques as well. This combined with new developments in digital technologies and big data analysis has led to unpreceded opportunities to much better serve the consumer. The challenge is to integrate these new approaches and apply them to the food arena.

Food and Me: Making Food an Activity. Traditionally, food producers only gain information about consumer thinking on a specific product from their purchasing behaviour or through specialized market surveys. This one-way communication has led to a poor relationship between consumers and food manufacturers. It has made the promotion of healthy eating and sustainable production difficult and has led to high failure rates of products. Distrust in solutions provided by food enterprises have ensued. However, with the digital revolution, completely new means to foster bidirectional and interactive communication have become available. The challenge here is to establish appropriate and effective forms and develop necessary content to facilitate the information flow between consumers and food producers related to food purchase, preparation and consumption scenarios. The obtained data needs to be processed in a meaningful way to extract trends and to identify gaps. For this, new data processing and transaction models will need to be developed.

Food Inventors: New Food Production and Delivery Models to Provide Better Access. In today's rapidly changing world, food consumption patterns are constantly changing. Food preparation in homes declines while food consumption through food services increases. This has left the consumer with a feeling of loss of control, being even more at the receiving end of a linear supply chain than before. As a result, movements have emerged that propagate consumer-led distribution models such as joint gardens and kitchens in a sense which turns consumers into producers themselves. New consumer-to-consumer business models emerge as a result of this trend. To date though, these efforts remain uncoordinated and unsupported and thus require a lot of efforts on behalf of the consumer. The challenge to be addressed is to better understand the extent and the variety of emerging business models in order to extract blueprints that enable consumers to become inventors and producers. Needs associated with logistics and micro-processing technologies have to be assessed, and the impacts on public health, food security and food waste have to be determined.

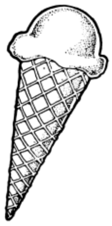
Footprinting of Food: Consumer Engagement in Sustainability. In a world where resources are becoming increasingly scarce, the need to enhance sustainability has become urgent. Food manufacturers have responded by developing many different sustainability indicators that, due to their great variety, have left the consumer quite puzzled. Individually-defined terminologies such as co-friendly, organic production, animal welfare, food miles, CO_2 and water footprints have raised more questions than they have answered. This is very unfortunate since efforts in sustainability could do much to gain consumer trust and involve consumers in protecting the environment. The challenge is to come up with a data-driven information system that structures and standardizes sustainability information across the food production system. Specialized data security and anonymization approaches will have to be developed, keeping in mind that such systems must be fully accessible to the many SMEs of the food sectors. This will need to be coupled with research that determines what knowledge would be suitable to engage and not just inform consumers.

The Smart Food Grid: Modular Food Production and Distribution. With the industrialization of food production, much research has been focused on developing ways to scale up processes to become more effective. However, with the increasing desire of consumers to have a customized, localized and diversified food supply available, new small scale food production approaches that are efficient and flexible will need to be developed. The challenge is therefore to develop techniques that can be readily modularized to allow for agility. In turn, this may require new quality and safety assessment methods for intermediates and final products, new packaging approaches, new delivery models and increased engagement of end-users as actors to finish personalization.

Expected Impact.

A successful execution of this R&I target will activate a decentralized innovation ecosystem allowing for the development of completely new business models in the food sector. Moreover, the transformation from a mass market oriented production system to a more decentralized, consumer-run system would do much to overcome the identified growing divide between food solution providers and consumers. Acceptance and understanding of the methods used in food manufacturing would grow, leading to alignment in goals of consumers and food solution providers.

Can you imagine?



The brand new flavor of the month ice cream in your local supermarket was invented by you!

It was made exclusively from local ingredients in small amounts. Friends and neighbors can share in the experience by purchasing your product from the local grocery. You receive a profit from your invention allowing your mini-business to grow.

Can you imagine?

You have just tried a new cheese-variety that was delicious. A mobile app allows you to provide the manufacturer with an immediate feedback, notifying the supermarket in your vicinity that they should keep the item in stock. Additional feedback from other customers received causes the product to be offered in a variety of serving sizes and with additional flavors the following week.

Can you imagine?

You had a great idea for a new food you wished to serve at your child's birthday. You shared this idea in an open platform and a small company contacted you and promised to work with your idea and deliver your wish.

Freshly made food delivered to your home address based on the menu you had created for the week giving you more time to spend time with your family on weekday evenings – realized by new network services.

3.1.1. Improving Insights in Consumers

Introduction

During the last decades, the field of consumer science has grown and led to a better understanding of consumer and societal issues related to food and eating. Simultaneously, new technologies have become available. Tools such as magnetic resonance imaging, eye-tracking and computer testing have been developed. Furthermore, it has become possible to collect and store large amounts of data easily. This volume and type of data was previously unavailable. These developments hold much promise in the sense that they can make new and deeper insights possible. However, so far the possibilities offered by these new developments have not been fully exploited. This hampers accumulation of consumer understanding and growth.

Background

The situation in consumer science of food. At the moment, a multitude of tools and methods are being used to assess variables in the food consumer science domain. However, in most cases the tools are difficult to use in large studies and across different samples and countries. This is due to their limited practical usability and lack of standardization.

New influences from adjacent sciences. Additional assessment tools, for example ones that gather consumer feedback beyond self-reporting, have become available for food research through disciplines such as psychology (e.g. projective techniques, implicit measures etc.) and the social sciences or from the design arena (co-creation).

New and emerging assessment technologies. New technologies (based amongst others on physiological measurements) impact on the consumer science domain. For example, automated observational tools, computerized testing, functional near infrared spectroscopy, electro-encelography, eye-tracking etc. have become available. However, these new tools are not always fully validated and often difficult to implement in large food studies.

New developments in big data for consumer science and engagement. Big data may be defined as large amounts of data collected without a specific theory guiding data-collection. Social media form a major source of such data. The interactive aspect of these media opens up new ways of communicating with the users. Today, specific databases which contain information on consumer behaviour in the food domain exist. Some examples are: (i) data on consumer household panel purchases, (ii) retail scanner data, (iii) loyalty card data. These sources have been little explored. We need to know better how to handle the large amount of data generated (big data) and how to ethically utilize such data. Also, sharing such data throughout the food channel is limited because the owners of the data do not want to lose the competitive advantage they can gain from it.

Thus, to enable a step-change increase in effectiveness of consumer research and consumer engagement in the food industry several issues have to be addressed: (i) lack of standardized tools; (ii) lack of cross-linking between studies/across countries etc.; (iii) limited use of the potential of the new technologies; (iv) limited use of consumer science big data.

Goals and Objectives

- To make a step-change improvement in the availability and usefulness of existing and new tools and technologies in foods consumer science.
- To develop standard approaches for developing and analysing big data in the consumer science field.
- To explore and develop synergies between new assessment tools and analysis of big data in the consumer science field.
- To enable sharing of data and information throughout the food channel and between different studies and countries in order to allow insights to be exploited effectively by industry, consumers and policy makers.

Rational and Significance

The relatively short history of consumer science in the food domain may explain the delay in the improvement of tools and the adoption of new assessment technologies. It may also explain the delay in the exploitation of the mass of data on consumer behaviour which have become available through both purposefully collected data (i.e.: scanner data, loyalty-card data etc.) as well as through more incidental consumer data (i.e.: social media). Reducing the delay can provide a step-change improvement in the level of consumer insight and consumer engagement. It will be beneficial for small and large food industries as they will have faster, better and more comprehensive insight in consumer needs. It will also be beneficial to consumers and society in general as it can facilitate consumer engagement in the food-industry.

Potential Approaches

- Improve and standardize a selection of key consumer science assessment tools for the food domain. Establish standards for developing and analysing consumer science databases and big data. Finally, investigate possible emerging opportunities resulting from these new standards, databases and analysis tools.
- The developments in this field will generate opportunities for creating much better consumer insight and engagement. Based on these developments opportunities for developing new products, new delivery means and new other services can be identified.
- Skills and competences in using and analysing new tools, new databases and new analysis techniques are necessary. Furthermore, as the insight generation is faster and more comprehensive implementation of the insights will require specialized skills.
- Tools and methods of data-collection may not always fit all groups in the population. For example, computer testing with infants and toddlers requires special tools. As this proposal intends to be inclusive for all it is suggested that special populations be

defined and addressed separately. Examples are differentiation on the basis of age, income and gender.

Expected Results and Key Performance Indicators

- A standardized selection of key consumer science tools in order to generate more effective consumer insights leading to higher success rates of new product launches and closer alignment with consumer and societal needs.
- Development of important new tools based on (new) technologies in adjacent fields.
- Innovative and standardized approaches to collecting, managing and analysing big data which will enable deeper consumer insight and sharing of data.
- Improved possibilities to pool data from different studies and sources in order to conduct more powerful analysis and to avoid duplication of efforts.
- Increased speed and effectiveness of consumer insights generation, resulting in more effective product and service development.
- Improved consumer engagement.
- Evidence-based recommendations for education programs increasing the skill and competence set needed to apply existing and new tools and big data in the food industry.

3.1.2. Food and Me: Making Food an Activity

Introduction and Background

The level of mutual understanding between food chain operators and the consumer is generally poor. Over the past hundred years, the industrialization of food production, the development of infrastructure, the dismantling of barriers to trade and the ensuing globalization of food markets have resulted in unprecedented efficiency gains. However, these very developments have also led to a state of affairs in which consumers and food producers have little contact with or understanding of each other. This has contributed to the difficulty for food producers to read consumer preferences correctly and has resulted in high failure rates of new products coming onto the market. From the consumers' side, the lack of understanding of how the food chain operates contributes to a lack of trust. This continues to be an issue even though it has long been identified as such.

The low level of alignment between consumers and the industry is a major barrier to making the industry contribute to solving some of the major societal problems related to food consumption. These include promoting healthy eating, more sustainable food production and food security. Realigning consumers and the food chain requires engaging consumers to the extent that they play an active role in bringing about tomorrow's food production. The European food industry faces a challenge to move from developing products and services *for* consumers, to one in which they develop these *with* consumers.

The high failure rate of new product launches mentioned above results in a waste of resources and, where products and services might contribute positively to health, in lower levels of consumer wellbeing. It implies that attempts to bring healthier and/or more sustainably produced products to the market often fail because of a lack of consumer acceptance. Many consumers are critical and distrust large scale industrialized food production. Revival of local production and short supply chains offer an alternative to consumers who seek transparency in production. At the same time, changes in communication technology and the way that media is accessed and used provides a unique opportunity for re-establishing closer contact between consumers and food producers regardless of location or scale of the production.

Goals and Objectives

The overall objective is to realign consumers and the food chain by exploring and implementing new forms of two-way communication between consumers and food producers. This overall objective is achieved through:

- Developing, testing and implementing new forms (the "how") and contents (the "what") of communication between consumers and food producers during shopping, meal preparation and consumption based on social media and app-based solutions that can be used in the shop, in the kitchen, at the dining table and on the go.
- Developing a better understanding of trends in consumer preferences by analysing data that are routinely generated by transactions, on social media, and in consumer panels, exploiting new techniques for mining of big data.
- Developing new business models for collecting and analysing consumer data, for providing information to consumers, and for disseminating consumer insights especially to SMEs.

Rationale and Significance

The current developments in information and communication technology (ICT) and changes in people's media habits provide a fertile environment for realigning consumers with the food chain and for getting the best out of both global, industrial and localized food production. The food sector has thus far been slow in exploiting the new possibilities these developments offer. Consumers have questions, inquiries, complaints, and are willing to interact with actors in the food chain provided they perceive that such interactions will have positive consequences. However, these developments also lead to the consumers being overloaded with information that they feel is not relevant for them. This perhaps even further diminishes the intended alignment. Engaging the consumer will require the development of new forms of interaction that limit information streams to what is relevant to the individual. Also needed is a two-way communication that takes place when and where the consumer wants and needs it. Establishing new forms of communication between consumers and the food industry will benefit all parties by enhancing transparency and encouraging co-creation. Consumers will get information when they need it, will profit from products better aligned to their preferences and will feel empowered in bringing about changes in the food supply. Food producers will be more successful with new product development and will regain consumer trust allowing their invaluable contributions to healthier eating and a more sustainable food production to have the desired impact.

Potential Approaches

- On the basis of a better understanding of consumer information seeking and media habits, develop new solutions for two-way communication in the shop (e.g., smartphone-based devices), in the kitchen (e.g., integrating information and communication technologies into kitchen appliances), at the dinner table and on the go; developing data mining techniques for analysing massive data streams generated by consumer actions to generate insights into consumer preferences.
- Develop business models for the generation, provision and analysis of data from and to consumers, and for the dissemination of consumer insights based on this to small and large companies at all stages in the food chain.
- Train actors working in new product development in food companies in the use of consumer insights based on these new sources of evidence in the new product development process.
- Train consumers in the use of tailored information during shopping, meal preparation and consumption.

Key Performance Indicators

- New forms of communication between consumers and food chain actors in the form of social media platforms, app-based solutions, and integrated solutions in the kitchen.
- New data streams both to and from consumers that can be used to generate insights into consumer preferences and their developments.
- Business start-ups that deal with the generation and analysis of consumer data and with the dissemination of results to food chain actors.
- New sources of consumer insights that both large and small food producers can exploit in the new product development process.
- Increased success rate in new product launches, especially for healthier products and products based on more sustainable production methods.

3.1.3. Food Inventors: New Food Production and Delivery Models to Provide Better Access

Introduction and Background

How people access and consume food is constantly changing. Food consumption in the home through meals made from ingredients bought in food stores is declining and the purchase of ready meals and pre-prepared meal solutions grows. Out-of-home consumption is increasing through restaurants, cafes and work canteens, and new concepts allow on the move consumption and snacking via vending machines, mobile and pop-up catering facilities. At the same time, some food production is becoming more localized. This shortens supply chains, as consumers use farm shops and engage in local and in-home production themselves. This is often made possible, or at least potentiated, by having current information and communication technology approaches embedded in them. These complementary trends increase the diversity in the ways that consumers access, prepare, produce and consume food.

Consumers traditionally access food largely through a supply-driven, gatekeeper-managed, linear delivery model. The manufacturer makes a product; the retailer or foodservice provider determines availability and consumers select from the choices offered. Through their gatekeeping characteristics, traditional production and channel delivery models influence consumer behaviour and consumer understanding of food. Changes in consumer demands and expectations at the location of purchase or consumption, and in the origin of and degree of food preparation required have however stimulated changes to this approach.

In traditional channel models, retailers and foodservice providers respond by marketing food solutions for “now, today, tomorrow”, “food on the go” or “food for later”. They use on-line purchasing and home delivery or collection models and new store formats and venues with a blurring of solutions (e.g. food to go in supermarkets) and an emphasis on experience.

New consumer-led channel models are on the rise. Some involve home production or localized micro-processing of some food categories (e.g. vegetable gardens, bread making, home brewing/baking) and local buying hubs by-passing traditional channels with consumer to consumer rather than business to consumer relationships emerge. This reflects a different type of engagement and involvement with food, characterizing consumers as co-producers or co-processors.

Such new combinations of food production and delivery models have potentially large yet currently unknown implications for consumers, food companies and policy makers.

Goals and Objectives

The overall goal is to identify the impacts of the new dynamics and diversity in food production and delivery models in terms of: (i) consumer perceptions (trust and satisfaction with the food system) and consumption behaviours (consumption patterns from a health, sustainability and waste perspective); (ii) business potential (for innovation and new business models); (iii) the economics of the food system (in terms of job creation), and (iv) policy (in terms of food security, food safety, and competitiveness). These goals will be achieved though the following objectives:

- Identifying and describing in detail the diversity and key features of new production and delivery models across Europe.

- Identifying the challenges of traditional channel business models and understanding the characteristics and operations of new business models for consumer access to food.
- Describing and quantifying the economic and innovation opportunities provided by new channel models. Of particular interest will be job creation in food production (technology), food logistics (including e-commerce), and supporting services (for food access and food/meal preparation).
- Assessing the implications for consumers of these changes in terms of their involvement and behaviour from diet and nutrition, food security and waste perspectives.
- Identifying the societally-relevant potential impacts on public health, sustainability of food providing systems, food security and food waste/sustainability.

Rationale and Significance

The new approaches to production and delivery channels redefine the roles and responsibilities of consumers, delivery agents and producers. They also have implications for supporting technologies, flows of information and materials and ultimately, innovation and job creation within the food system.

The traditional channel need to be analysed in terms of the options presented by the growing food to go - out of home and on-line shopping markets. For example, as on line-shopping and home delivery models evolve, do consumers purchase less healthy, do they perform less home cooking and meal preparation, and does this result in more waste from longer fragmented supply chains? Likewise, the question arises whether there are opportunities for behaviour change?

For the new channel models, the potential for scaling-up of these approaches needs to be established. Many small-scale examples of such models exist and those models that prove successful in an economic ecosystem would be expected to spread. This makes it imperative to understand their functioning and their potential impacts on the food system. The limits to the spread of home and localized production and processing are unclear, certainly in terms of what food products and processes are suited for these approaches and whether they could succeed in different societal groups. There are potential market opportunities for material and services serving this type of production model, such as in-home technologies such as 3D printing, raw materials for home production, support services and information, and a possibly re-configuration of kitchens and other elements of the home.

Potential Approaches

- Research: map, demonstrate and assess the impact of the emerging options in localized production and of different food supply systems on the role and responsibilities of actors in the food chain in different consumer contexts (national versus regional; urban versus rural; young versus elderly).

- Innovation: construct a range of exemplary business models for new production and delivery models to act as catalyst for innovation and new commercial opportunities.
- Education: develop information and communication mechanisms to increase awareness and understanding of the innovation and business opportunities these new models represent.

Key Performance Indicators

- Credible inventory of consumer acceptance, trust and satisfaction and consumption behaviour impacts (health, safety, sustainability and waste) of the new and increasingly diverse production and delivery models.
- A map of the economic opportunities that the new production models represent including, but not limited to home appliances, ingredient and raw material supply and service solutions.
- Proposed sustainable business models for new-channel configurations allowing consumer or community driven food provision.
- Specific, critical issues of public interest or risk for consumers identified for these new approaches, including those in areas such as public health, food security and food waste issues.

3.1.4. Footprinting of Food: Consumer Engagement in Sustainability

Introduction and Background

Food products are sometimes labelled with different kinds of indicators many of which are related to specific aspects of sustainability, such as e.g. fair trade, eco-friendly or organic production, animal welfare, food miles, CO_2 and water footprint, etc. The lack of a clear definition and proof of impact has led to much consumer confusion and in the end led to disbelief and distrust, especially because many retailers and manufacturers have started to use their own indicators, which are considered to be subjective. It does not make sense to create yet another indicator. However, it is important to engage the consumers themselves, and let them decide which information should be combined into information that makes sense. In a way individualization of sustainability data about food products is needed.

Of course, the big data revolution nowadays enables one to very quickly combine and correlate massive amounts of data (much of it is unstructured). At the same time, the emergence of more and more sophisticated, self-learning artificial intelligence systems enables us to not only collect, but also to interpret information. Already the first tools are available that enable obtaining structured reports created by artificial intelligence (Fig. 5).

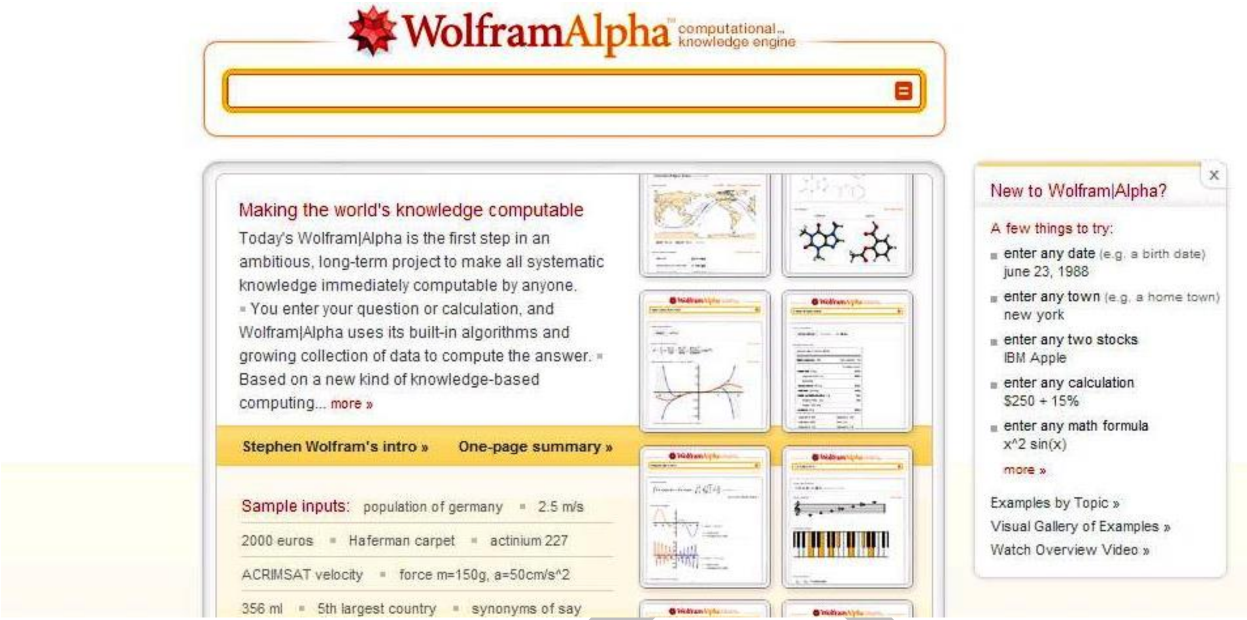


Figure 5. An early example of a query compilation system based on artificial intelligence is Wolfram Alpha; in specific, non-open-source areas, even stronger examples are available (e.g., in the area of the assessment of medical information).

In this action, a system will be developed that enables the consumer to actively conduct a query (e.g., using a scan of a product with a cell phone camera) such that exactly the information relevant to a particular consumer is reported back. Depending on the wishes of the consumer, this could be concentrated around animal welfare, dietary requirements, CO_2 footprint or other aspects that will be included in the report. This can only be done by utilizing new technologies in the area of big data, but also includes an active involvement of producers and consumers themselves, since relevant data has to be made available and interpretable. Although there are intellectual property and competition issues to be considered, this will greatly increase the transparency of the food system as a whole.

Goals and Objectives

A system is to be created that allows consumers to actively query for a set of related agro-food information on a specific product that they individually look for and find important. To accomplish this

- Data, either structured or unstructured, on the production and conversion of foodstuffs needs to be made available and continuously updated, since product lifecycles are often quite short. Data anonymization and data security strategies need to be considered. This requires collective action by producers, retailers and many other actors. Ideally, such action is coordinated by a EU wide organization. Special consideration should be given that SMEs will have a system available that does not significantly add to costs and that does not put unnecessary reporting burdens on them.
- Research has to be done on what consumers would like to know, what knowledge would actively engage them, and what the best form of presentation would be.

Furthermore, as information overload may be an issue, an investigation including consumer research and exploration of possible solutions for information overload is needed.

- A search and reporting system based on the use of these data should be created. This does not have to be built from scratch, but may make use of existing systems (e.g., Google, Watson, etc.).

Rationale and Significance

The current overabundance of sustainability indicators has led to confusion and distrust with consumers. More passive labels would only add to this, and are not the solution. With the consumer actively involved in obtaining data, and having active influence on both content and presentation of the results of an individual query, it is expected that people will become more involved and will have a greater trust in the agro-food production as a whole. The transparency that this gives may encourage consumers, especially when more detailed queries will yield more information. In addition, such a system will provide two-way information. The types of queries, and the requested forms and combinations of the results will yield a wealth of information to the actors in the chain (producers, retailers, etc.). The system will require that major players provide access to their data, with results to be anonymized, while the information coming back from individual consumers will provide the same players with better insights into the motivations and wishes of consumers, almost down to the level of the individuals.

Potential Approaches

- Creating an open source system based on open information. One can start either from the data end, or from the consumer end. If one starts from the consumer end, one may develop a system, which collects data from the internet, and then compiles this, using artificial intelligence, into a coherent report towards the consumer, who then would use an app to access it while walking in the supermarket, or while web shopping
- Starting with a concerted action on data access. One may also start with a consortium that agrees to make data on production and sustainability available for the platform. From this, a query and compilation system can be built that gives consumers and others access to the data and the analyses.

Key Performance Indicators

- Increases in the number of queries conducted via such systems.
- Increases in the number of participating agro-food chain players.
- New data-centric agro-food businesses.
- A measurable increase in the trust level in the agro-food system.

3.1.5. The Smart Food Grid: Modular Food Production and Distribution

Introduction and Background

For long the development of the food chain was driven by scale, i.e. from primary production at large farms over large production units to large distributors and retailers. There is now a demand for mass customization rather than mass production. Some consumers wish small-scale customized food production closer to them. Proximity of production and consumption can reduce food waste but requires that existing food processes adopt the use of new raw materials and shorter food chains. Modularization at various stages of the food value chain will give the opportunity for new business models and will contribute to social, economic and environmental sustainability.

Food production and retail have become centralized due to economies of scale. This has made the consumer a recipient of products made sometimes far away. Retail and food delivery are under pressure to change mainly due to digitalization and demand for personalization and customization. There is a need of flexible processes that are agile and enable fast adaptation to changes in consumer demand. Food supply chains are in many instances to at least a certain degree global and may therefore be impacted by regulations. Modularization may also be a very valid approach to convert packaging systems from passive ones to processing aids. Typically, packages act to protect products from external influences (e.g. mechanical stresses, oxidation, microbial spoilage) after manufacturing. In addition, they are crucial for communicating information about the content of a package to users. However, one could foresee that as processing moves from large scale operations serving mass markets to smaller ones, these could also become vehicles to transform materials to food products, e.g. by fostering and controlling fermentation or by catalysing enzymatic reactions. This is not a completely new approach. Indeed, household containers have in some cultures been used for a long time to generate foods (e.g. the production of Kimchi in refrigerators using glass jars). If one takes this through to a new level, a completely new and decentralized way of producing foods could be developed.

In the particular case of Europe, the food supply chain has a converging-diverging shape (Fig. 6). It is controlled by the distribution sector (buying desk), because of its enormous concentration. The weaker actors are especially the small farmers and producers on the one side, and the consumers on the other.

Modularization will not only affect food processing, but also the food supply chain, and will enable the creation of new distribution businesses that contribute to the sustainability and diversity of the system. Nevertheless, modularization faces some drawbacks such as the loss of advantages of economies of scale.

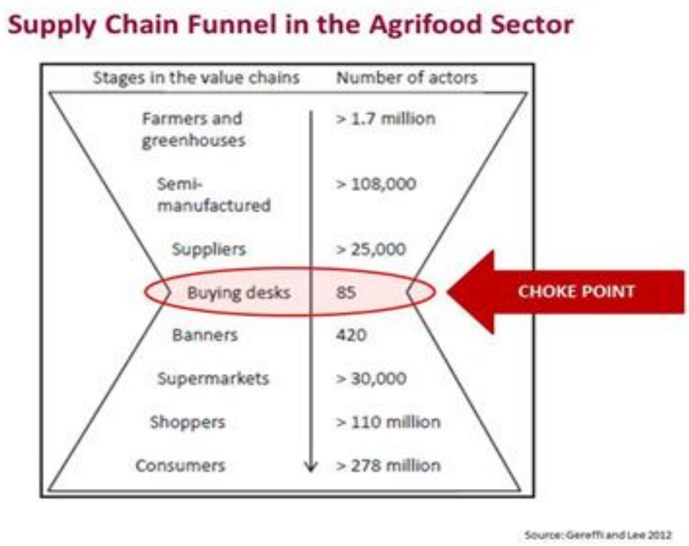


Figure. 6. Double funnel market structure of food supply chain in Europe (2012).

Goals and Objectives

The objectives are to:

- Adapt food processing to small-scale production and to increase its efficiency. This will be done by adding value, creating new intermediate products and by using digital technologies for process control systems.
- Adapt packaging to modularization and vice versa.
- Adapt the logistics channel to modularization and to modularize the logistic channel itself.
- Develop or adapt traceability tools appropriate for the modularization process which assist in safety assessment and in delivering a quality label for the product.
- Involve end-users as actors in the process, allowing for culinary diversity and personalization of products.

Rationale and Significance

The approach needed will stimulate clustering of intermediate products of small or medium producers to operative networks and create new service structures. It will create new value chains and new business models. It will also create or reinforce new distribution models that will assist in increasing the competitiveness of modularized production. Modularization may disrupt existing value chains and create demand for new products, ingredients and intermediate products, and allow new concepts for pre-processed ingredients. It will also enable more local food production and diversify the food culture.

Potential Approaches

Enabling technologies include the internet of things as a source of information but also the internet as a way to supply products. Cloud computing will enable remote operations and systems control, as well as allow traceability. It will involve the development of small mobile processing plants, and new models of logistics and advanced data analytics that fit to modular systems. Definition and standardization of intermediate products will be important elements of the development. Moreover, systematic conversion of packages from passive protection systems to active processing aids will be executed following the development of the necessary scientific and technological means.

Key Performance Indicators

- Reconfigured distribution channels and delivery modes (family and small businesses).
- Degree of food sovereignty - self-sufficiency.
- Reduced the carbon fingerprint.
- Sustained bio-diversity of local ecosystems.
- Improved sustainability of local farms (rural areas) and local operations.
- Enhanced process efficiency

3.2. R&I Target 2: Providing the Basis for a More Personalized and Customized Food Supply

Aim: In the future society, every citizen will have access not only to sufficient and affordable food, but will have exactly the "right" food for him or her in terms of his/her preferences and physiological and psychological needs. Diverse choices will be available that make eating a cultural and social experience while simultaneously maintaining one's health and agility in various life stages. Our food will communicate these benefits to us via electronic means allowing us to be informed about it at all times.

R&I Target 2 is about achieving this goal by fostering developments in laboratory science approaches and in the social sciences to permit a new ambition of understanding both of why and how consumers choose and eat food and also how food interacts with our bodies after it is ingested. This deeper understanding that these approaches will give, will provide the basis of the design of intrinsically healthy foods that fit into the myriads of lifestyles that modern society includes. In order to develop these foods, one first must know in detail both the ways in which food is valued and what food actually does inside us after it is eaten. For this, four key areas have been identified that deserve priority: (i) conducting research to better understand how food appreciation can be modulated to achieve maximal satisfaction, (ii) developing new ways of enabling food to communicate with us and inform us about itself to allow for personalization, (iii) understanding what happens to various foods after they have been ingested, especially in terms of impact on our gut microbiota, and (iv) finally how this translates in terms of development of non-communicable diseases.

Implementation

The action items proposed here fall into two different areas: (i) how food fits into our lives and (ii) what food does in us and to us.

<u>How food fits into our lives:</u>

The Food I Love: Appreciation of Diversity in Food and Eating. In the European context, food appreciation, how it is moulded by culture, and how it modulates how food is consumed and the consequences thereof in terms of health, wellbeing and sustainability will be investigated.

(Tr)eat Me: Dietary Approaches for the Prevention of Non-Communicable Diseases. State of the art methodologies from epidemiology, medical and analytical approaches and social sciences will be used to greatly accelerate and add detail to our description of the effects of diet and lifestyle on non-communicable diseases.

Packaging 4.0: Intelligent and Communicating Packages. Active and intelligent packaging will be developed by taking advantage of new knowledge on materials (including nanotechnology insights) and the possibilities that new generation connectivity brings.

What food does inside us:

In Silico Food Design: Understanding Food Digestion. A multifaceted approach will be used to unravel the mechanisms of micronutrient digestion from complex food matrices. Experimental cell biology and human intervention studies will be accompanied by modelling approaches and this mechanism directed research will itself be complemented by epidemiological, big-data driven work on existing and newly generated information.

The Ecology Inside Us: Food Meets Gut Microbiome. Basic research on functional aspects of the intestinal microbiome will create the basis for establishing how specific foods effect human physiology via the microbiome.

Foods for Tomorrow: New Concepts and Technologies to Assure Consumer Health and Wellbeing. The last action item in this target is an overarching initiative in the form of a forerunner project. It will take the concepts of alternative food sources and upgrading of secondary product streams to a new level of ambition. In this initiative the design of sourcing, processing and nutrient characterization will target consumer acceptance as a key end point.

Impact

A successful execution of this research and innovation target will lead to a societal strategy that ensures that consumers not only can eat the food needed to live life to the fullest extent, but also have the means to do so. The work to be executed here will bring forward key insights into how the consumer interacts with food. It will provide new knowledge which industry can use in the design of new intrinsically healthy products that fit into specific lifestyles. It will describe in detail the effects of diet and lifestyle on the development of NCDs in such a way that specific strategies can be designed, developed and communicated in order to effect real positive changes. It will enable an understanding of how micronutrients and bioactives are made available to their target tissues in the human body. It will define approaches to potentiating bioavailability through technological innovations. It will take the knowledge of effects of foods on the human microbiome to a level that can be employed in positively affecting health via food and diet, and bring a new generation of ingredients and foods from alternative sources that are both sustainably sourced and welcomed by the consumer.

Can you imagine?

Our gut contains micro-organisms which all together count higher that all the cells constituting our body! And they can be modulated by the food we eat. Foods ingested during meals contain ingredients and microorganisms that impact gut microbiota and health. And you will feel good if your microbiota is happy!
As Hippocrates said: let food be your medicine and medicine be your food!

Can you imagine?

Your always wanted to know where exactly the fruits of your favorite multivitamin juice came from and whether they were all fair traded. Scanning a bar code on the back of your juice package allows you to access the wanted information. From previous scans, the system has learned that you are also watching your vitamin and mineral intake, and informs you automatically how a glass contributes to your daily levels.

Can you imagine?

You have this app that really helps you making the right food choices. It measures how much you move, how much you rest. When you take pictures of what you eat, and what you want to eat, it will give you advice to help you keep your health … in a friendly way. “Please, no more of this today. Let’s eat that tomorrow”, or “Why don’t you have an apple and some yoghurt – we could do with some calcium”, or “great choice, that will give us vitamins we still need today” – allowing you to stay healthy while enjoying food.

3.2.1. The Food I Love: Appreciation of Diversity in Food and Eating

Introduction and Background

Food consumption is central to human life, not only in terms of nutritional needs (survival), but also in terms of social (relationships), emotional (life satisfaction), and identity-related (food culture) needs. With food (still) available in abundance, and food safety levels largely secured, food may easily be taken for granted in the European community. Despite increasing similarities across Europe, consumer appreciation in terms of the perceived value and satisfaction from food and eating, shows intriguing and valuable, yet poorly understood, differentiation. What (individual) consumers value and have concerns about may relate to any part of the food value chain and system, including primary production, processing and manufacturing, distribution, purchase, preparation, eating and even its disposal. Lack of understanding of the diversity in what (groups of) consumers value in food and eating across Europe leads to suboptimal decisions as it focuses on a heterogeneous average rather than catering for the diversity and the individual needs. Enhancing food appreciation at the individual (and sub-group) level increases consumer satisfaction and wellbeing, allows business value creation and capture and policy level interventions (education and regulation).

The term food appreciation has different meanings in different parts of Europe which differ between ethnic groups, (regions within) countries, age cohorts, socio-economic groups, education levels and even identity-based groups. Food appreciation changes over time as a result of new provisions in the market place, as well as from learning and education. Hence it is important to track developments in food appreciation over time, in different groups and as a causal result of interventions (e.g. education).

Understanding food appreciation will allow better alignment of its supply to the diversity in valuation by European consumers. This will bring economic value in terms of willingness to pay, consumer satisfaction and reduce food waste. Many economic sectors, including primary production, food processing and manufacturing, food distribution (both retail and e-commerce) and food provisioning [including (institutional) catering] will benefit from this, as will also peripheral industries (e.g. information and communication technology services).

Goals and Objectives

The goal is to (better) understand and quantify the *diversity* in what European consumers value about food and eating as a basis for the European Food System to realize the full potential of the economic, social and sustainability value of Europe's food culture. This is achieved through the following objectives:

- Identify the meaning and content of European consumers' food appreciation and its determinants from the whole food system perspective, including primary production, processing, purchase and consumption and food disposal.
- Map the geographic diversity in food appreciation across Europe, with focus on similarities as well as diversity across different countries, regions, socio-economic groups, food-related lifestyles and value structures.

- Identify the social diversity in food appreciation across different European consumer segments, and the diversity in (i) current food and meal type choices (e.g. high versus low level of processing), (ii) patterns in current consumption practices (e.g. what are the implications for health, sustainability and wastefulness in current practices), (iii) level of satisfaction, wellbeing and (iv) willingness to pay.
- Identify the untapped potential for new products, new delivery models, and associated services (technology and information and communication technology) to create value.

Rationale and Significance

Better consumer appreciation of food and eating has value in the economic sense (higher willingness to pay), in a social sense (higher satisfaction and social capital around food and eating), and in a sustainability sense (less food waste and higher recognition of health and sustainability). Insight into the heterogeneity of consumer appreciation, while at the same time also appreciating the similarities, may give us more diversified and better customer-aligned food provisioning across Europe. This will benefit both SMEs targeting specific niches and large manufacturing industries catering for larger groups. Aligning the diversity in supply with the identified diversity in food appreciation will increase (i) consumer satisfaction and commitment, (ii) extract larger value from the product supply (willingness to pay), and (iii) cross-selling of new product and services (innovation and job creation) to further support food appreciation.

Potential Approaches

Research: conceptually and empirically unravel the concept of food appreciation, its scope (e.g. acceptance of high versus low levels of technology in food production and processing, social value from eating occasions), its determinants [history and (food) culture] and its consequences (in terms of health, sustainability and wastefulness of consumption practices, consumer wellbeing and quality of life).

Innovation: identify and empirically validate the untapped potential for new options for products, delivery and services that add value to segments of consumers and thereby further support consumer appreciation of the food system.

Education: extract evidence-based recommendations for education programs for better understanding and recognition of diversity in food appreciation within European culture.

Key Performance Indicators

- Insight into the similarities and diversity across Europe in what consumers do value in food and eating behaviour (mapping diversity in of food appreciation).
- Assessment of the impacts of food appreciation for current food consumption practices in terms of consumers' health, sustainability and food waste.

- Identification of the economic potential of product and service innovation for better answering the diversity in consumer satisfaction at an individual or group level.
- Identification of the opportunities for better food and eating appreciation in out-of-home situations, including institutional environments, and its impact on health and wellbeing.
- Evidence-based recommendations for education programs to increase understanding and recognition of diversity in food appreciation within European culture.

3.2.2. (Tr)eat Me: Dietary Approaches for the Prevention of Non-Communicable Diseases

Background and Rationale

The way of working and the age structure of the population in Western Europe has significantly changed over the last decades. It led to a significant reduction of energy intake in the diet and, especially in the aging population, to a substantial higher need for optimal nutrition supplying a full set of micronutrients rather than calories. It is recognized that the role of nutrition is crucial for health and directly related to the health cost of society. There is a need for tailored nutrition depending on requirements related to age, gender and genotype. Furthermore, the microbiome has an impact on health, which is currently increasingly investigated.

Epidemiological associations between the intakes of nutrients, foods or food categories, and dietary patterns with health outcomes are frequently not supported by results of randomized controlled trials. In addition, many non-communicable diet-related metabolic diseases share common comorbidities, involve multiple organ systems, and are multifactorial. For example, type 2 diabetes is not only related to cardiovascular disease, but also to cognitive impairment, mood disorders, and sarcopenia. Such common comorbidities indicate shared underlying causes and pathways such as low-grade inflammation, impaired glucose and lipid metabolism, impaired vascular function, ectopic fat deposition, intestinal dysbiosis and environmental stressors. Common underlying causes and pathways may also mean that there are shared solutions. These considerations urge the need for targeted hypothesis driven long-term intervention studies, not solely focusing on accepted biomarkers, but also on functional intermediate endpoints or even hard endpoints.

Goals and Objectives

- Identify and validate new dietary approaches to prevent NCDs and their co-related comorbidities, and to improve health in specific population groups, thereby progressing towards (semi)-personalized nutrition.
- Target shared mechanisms and pathways by dietary approaches to prevent NCDs and their co-related comorbidities.
- Identify and provide mechanistic underpinning for dietary approaches to prevent NCDs and their co-related comorbidities and to improve health.

- Develop and validate new innovative, multidisciplinary approaches to predict dietary responsiveness.

Rationale and Significance

Dietary and lifestyle intervention strategies specially designed for specific population groups, e.g. elderly and children, and their validation in well-powered intervention studies will support cost-effective strategies to reduce the socio-economic burden of NCDs. This will also improve competitiveness of the European food industry by generating sound evidence of the benefits of healthy foods and dietary habits.

Potential Approaches

- Carry out hypothesis driven long-term studies to target shared mechanisms for preventing multiple (comorbidities related to) NCDs by dietary approaches.
- Improve predictive approaches (e.g. challenge tests, isotopically-labelled substrates, multi-omics profiles, 3D in vitro models) and biomarker profiles as well as algorithms to link these to responsiveness to dietary interventions.
- Implement up-to-date approaches to optimize compliance for effective life-style changes to prevent multiple (comorbidities related to) NCDs.
- Develop novel intervention strategies and adherence to healthier lifestyles by the use of digital technologies (apps, web-based, etc.).
- Encourage the development, validation and routine use of new and emerging potential biomarkers to support a healthy nutritional status and behaviour (e.g. apps, saliva, and dried blood spots).
- Determine what measures motivate people to incorporate such novel intervention strategies with long-term health consequences in current decision making processes with respect to food.

Key Performance Indicators

- Availability of new dietary approaches to prevent NCDs and their related comorbidities.
- Availability of an efficient integrated toolbox for identifying the most promising foods to be tested in specific population groups.

3.2.3. *In Silico* Food Design: Understanding Food Digestion

Introduction and Background

Many of the NCDs in our society are related to an unbalanced diet. Increased intake of specific ingredients should lead to better health and quality of life. However, simply adding health promoting ingredients often does not work. This points to the key role of the food matrix in making specific ingredients available for our digestive system. Until now, the specific mechanisms that play a role during food digestion are not well understood. Digestion is massively complex and involves (bio-)chemical and microbiological phenomena while the gastro-intestinal tract impacts on the properties of the food that is digested. In addition, digestion is affected by very complex control and feedback physiological mechanisms. Understanding digestive processes will enable us to understand how we can incorporate ingredients such that they will be taken up efficiently and indeed will have the desired health effects. This may then be done by incorporation in a matrix, by encapsulation, by complexation, or whatever mechanism is most effective for the desired bioavailability. Current *in silico* models can semi-quantitatively predict the fate of macronutrients (Fig. 8).

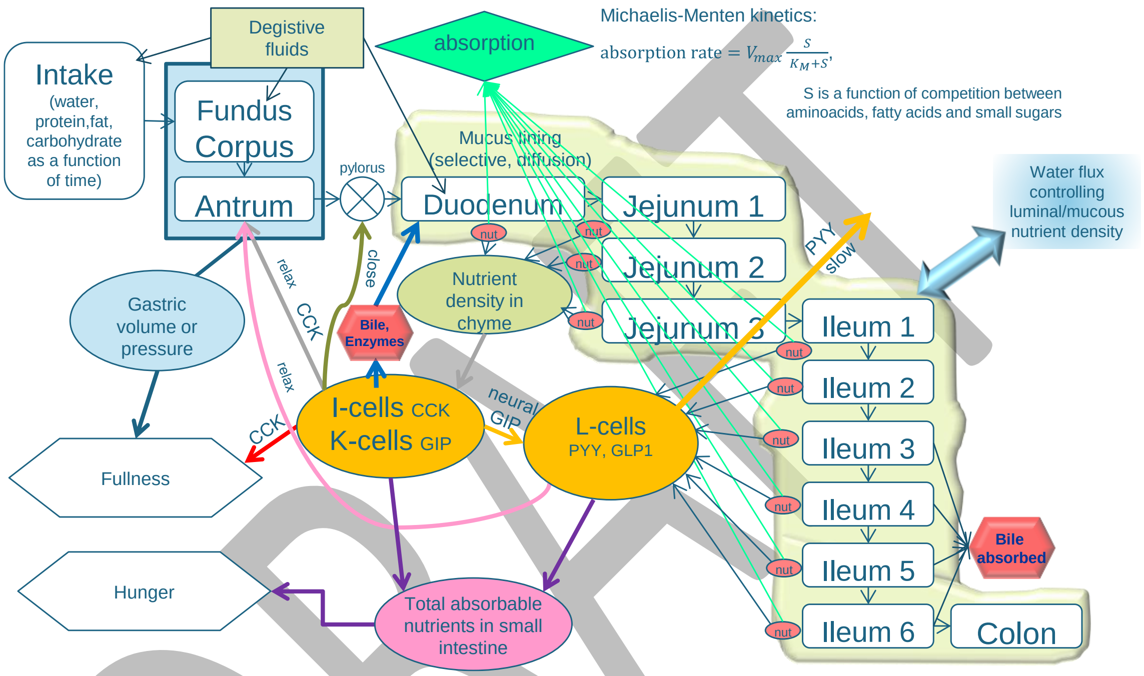


Figure 8. Schematic illustration of the complex processes involved in determining the fate of nutrients after consumption (NIZO Food Research).

Moreover, the fate of specific functional micronutrients cannot be predicted at present. This then gives true functionality to functional foods: not just the addition of healthy ingredients is important, but the structural incorporation in the matrix which is optimized towards achieving the right metabolic effect. In other words, here, the design of products is inverted. One starts from the desired metabolic effect, and from this, the product is designed.

Goals and Objectives

- Enhanced functionality by matrix effects, encapsulation and/or synergistic effects will allow developing new ingredient functionalities. This will require a concerted action to understand and model the digestive tract in order to generate structure-function relationships that allow for reliable prediction and design of matrix effects on the digestion of micronutrients.
- Understanding the fate of food matrices and the digestion of individual micronutrients in the gastro-intestinal tract and capturing it into an in silico open source model. This

will be the result of a concerted effort concentrating on a specific aspect of the food matrix or part of the digestive tract.

- Ensure that enhanced bioavailability is turned into products that consumers will find transparent and trustworthy.

Rationale and Significance

The actual health effects of functional ingredients are at the basis of any functional food. They greatly depend on the matrix in which they are embedded and on the direct environment and shape of the ingredients under study. For example, the type and form of complexation/ chelation of iron is of great importance to its bioavailability. In addition, the matrix in which it is embedded is also important. The same holds for many other micronutrients. Increased understanding in this area will provide major opportunities for functional foods, facilitate the acquisition of evidence for measuring and claiming health effects. While in many cases it is daunting to model a complex system in silico, such models will very quickly lead to the white spots where more research is needed. At the same time, they will serve as a platform connecting the different work pieces done by different partners over Europe. The new possibilities offered by big data approaches will certainly be of great help in such efforts.

Potential Approaches

- Creating a concerted effort for studying micronutrient digestion. Non-invasive techniques (e.g., use of ultrasound, magnetic resonance imaging, sensors-in-pills, and stable isotope methods and monitoring plasma levels), invasive techniques (with animal models), and *in vitro* techniques will be combined into a large-scale, Europe wide program that unites many different partners to form a concerted effort for studying the fate of micronutrients in the digestive tract.

- Understanding the interaction between complexation/chelation/encapsulation and matrix effects to benefit the bioavailability of micronutrients. Here, a ‘design’ approach will be followed. The direct form of micronutrients will be changed through encapsulation and/or complexation/chelation, and the effects and cross-effects between micronutrient form and overall matrix will be studied.

- Mechanistic *in silico* modelling. The above open source modelling system will guide research towards parts that are still not understood and crucial for understanding bioavailability. Different approaches are possible, but it is important that they lead to mechanistic understanding.

- Big data approaches for *in silico* metabolic modelling. A logical extension of mechanistic modelling is using big data approaches. These may not only be based on existing database, but may also be combined with cohorts that are monitored using modern methods such as the use of wearables.

Key Performance Indicators

- Increased understanding of micronutrient functionality. This may lead to a new generation of ingredients capable of better addressing malnutrition (such as e.g. hidden hunger).
- Outcome of *in silico* modelling. This can reduce costs by limiting the extent of intervention studies. It may also reduce the number of animal studies required, thereby addressing animal welfare issues.
- Executed big data approaches. These will lead to new insights with respect to synergistic or antagonistic actions of ingredients.

3.2.4. The Ecology Inside Us: Food Meets Gut Microbiome

Introduction and Background

Nutrition and diet are essential for health and well-being. Ingested foods and drinks are "processed" in the gut. The gut serves two essential functions: a digestive one (digestion of foods and transfer of nutrients to the host) and a barrier one (protecting the host from invading microorganisms, toxic compounds and allergens). The gut is a complex ecosystem that remains at homeostasis in healthy subjects thanks to a constant cross-talk between key players: the microbiome, the epithelial barrier, the associated innate and adaptive immune systems and the enteric nervous system (Fig. 9). The gut ecosystem is also connected to the brain by a bidirectional exchange of signals via what is designated as the gut-brain axis. It is increasingly recognized that the gut-brain axis is influenced by the microbiome, which is then referred to as the gut-brain-microbiome axis. Disturbances of this ecosystem (such as a "leaky" gut barrier or changes in microbiota diversity) have been increasingly associated with several non-communicable diseases including diabetes, sarcopenia, cardiovascular diseases, allergy, autoimmune disorders as well as psychological co-morbidities such as depression and anxiety.

The gut ecosystem is shaped by the genetic background of the host but is also largely influenced by environmental conditions, including diet and living conditions. In terms of prevention of non-communicable diseases, the influence of the maternal health and nutrition on the long term health or risk of disease development increasingly receives attention. At present, there is a focus on metabolic and immune imprinting, but this is progressively extended to mood and cognitive functions. It thus links physiological and psychological responses to food intake. It is recognized that there might be long term effects already initiated *in utero* during pregnancy.

However, not only in the early years does the gut microbiota - food axis play an important role. There is an urgent need to acquire additional knowledge on the aging digestive tract (e.g. aging of the digestive system *per se* and its absorption capacity) and the interaction between immuno-senescence and cognitive decline, nutritional needs, and lifestyle. Specific dietary and nutritional recommendations for aging people are basically lacking and should be established taking better characterized physiological needs into account, thereby realizing that lifestyle and psycho-social environment may play a critical role in healthy aging.

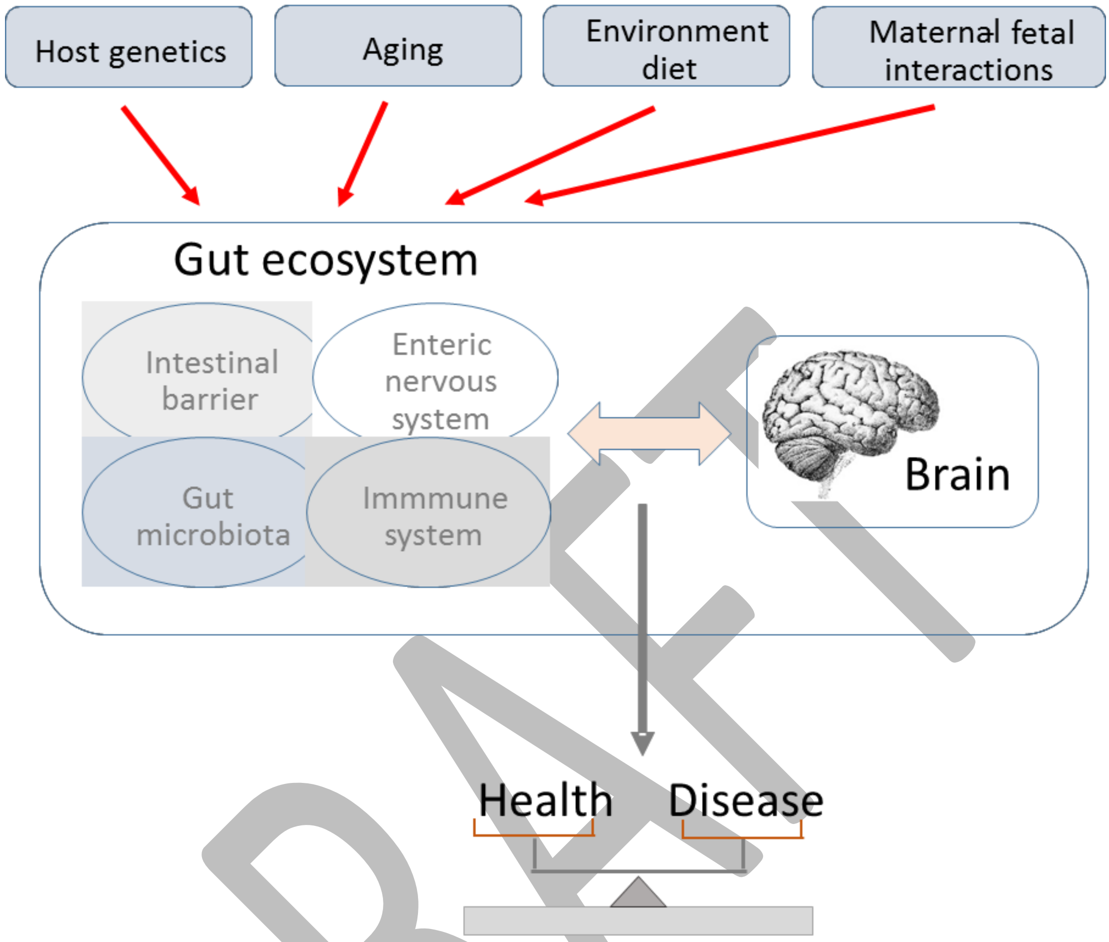


Figure 9. The gastro-intestinal tract is the ecosystem where food impact on the host is first initiated.

To maximize economic and consumer benefits of a microbiome-optimized nutrition, an integrated research approach of the gut ecosystem and a better understanding of the role of food and nutrition in the gradient from health to disease during different periods of life is needed. In doing so, it is necessary to take food structure and function and food microbiota into consideration, while examining key partners such as the gut microbiome, immune system and digestion/tolerance to foods and their effects beyond the gut. It further becomes increasingly critical to provide consumers with a more comprehensive and fact-based view of the potential risks and benefits of food constituents and processed foods via their impact on the gut ecosystem. This approach is strongly connected to the assessment of potential health benefits of new food materials, novel processing approaches and to consumer research.

Goals and Objectives

The goal of this action is to gain a comprehensive and holistic understanding of the central gut-brain-microbiome axis in order to develop new functional foods or nutritional recommendations that lead to established or highly resilient gut and overall health. To that purpose, research should be conducted to

- Gain a better understanding of the impact of variation in microbiome function (rather than solely composition) and go beyond descriptive correlation studies to establish where this can be targeted by diet to achieve meaningful benefits.
- Clarify the cause-consequence relationships in the data described to date to generate working hypotheses that can be tested in well-designed human intervention studies.
- Establish to which level NCDs can be reduced/prevented by nutritional interventions that impact on the microbiota, the gut barrier, the immune system and/or the enteric nervous system.
- Create awareness that a health benefit should not be obtained at the expense of another health benefit by conducting integrative studies on the different physiological effects induced by foods or food constituents.

Rationale and Significance

The intestinal microbiome currently rightly receives much attention from the scientific community - whether in academia or industry - but also increasingly from consumers and governmental and non-governmental organizations. However, current expectations for applications derived from microbiome research are based mainly on association studies. The cause-effect relationship of the current observations remains largely unexplored, which may lead to partial or even wrong conclusions. This may in turn lead to embarking on human interventions studies with limited chances of success. It also needs to be further investigated whether meaningful effects on human health-related outcomes can be feasibly and sustainably derived from targeting the microbiome through dietary interventions. The absence of such research may perpetuate unjustified emphasis on the microbiome as a route for nutrition intervention on the one hand, and jeopardize the possibility to design the appropriate health promoting foods on the other. Such possibility relies on an improved understanding of the impact of foods/food components (including its microbiota) on the host gut ecosystem and could truly impact on the prevalence and treatment of non-communicable diseases.

Potential Approaches

- To develop ecology and function approaches to study the intestinal microbiome and move from description to function (including metabolomics, metaproteomics, metagenomics) with a strong emphasis on evidence of realistic diet-inducible effects in human systems.
- To perform mechanistic studies (preclinical) with foods/food constituents, raw materials, processed foods, functional ingredients and their related microbial ecology, on the different components of the gut ecosystem in order to clarify whether, for example, the observed changes in microbiota composition are a cause or a consequence of the correlated modulation of a health parameter and judge the potential effect sizes that might be derived from dietary interventions.

- Based on sound and educated hypotheses, test food components/processed foods/nutritional ingredients in small proof-of-principle human trials with well-defined primary outcomes (i.e. 'go / no-go' criteria). Develop the right "models" to support this research step.

- To generate new hypotheses by integrating multiple physiological readouts as exploratory measures in these studies and linking them to microbiome composition/function by using a systems biology approach.

- To test specific ingredients or matrix or processing effects to determine whether structure-function relationships can be established for health effects of diet acting via the microbiome.

- To characterize the ageing gut ecosystem in order to generate scientific underpinning for potential interventions and developing specific nutritional recommendations.

- To understand the role of the gut-brain axis and its interaction on behaviour and well-being, influencing decision making processes with respect to foods.

Key Performance Indicators

- Provision of a convincing description of the microbiota function, its impact on health parameters and cause-effect mechanisms proposed or elucidated to underpin meaningful health effects for dietary interventions acting via microbiota.

- Development of a methodology to align preclinical research with small human intervention studies in order to "validate" preclinical assays.

- Building of coherent cases and performing sound experimental studies that address the impact of food structure, function and microbiota on the different components of the gut ecosystem.

- Identification of characteristics of the gut ecosystem (e.g. key microbiota consortia) that can be used to stratify subjects especially for the small scale human studies.

- Meaningful estimates of the health impact of dietary interventions that act via modulation of the microbiota.

3.2.5. Packaging 4.0: Intelligent and Communicating Packages

Introduction and Background

Industry 4.0 denotes the concept of a manufacturing system with full integration of cyber and physical technologies, wherein machines and devices communicate with each other, as well as with users. In the context of a rapidly evolving digital world, one can envision that packages provide an interface to implement an Industry 4.0 concept in the food systems arena. The proposed action item involves the exploration of technologies that go beyond classical active and intelligent packaging approaches and allow to fully leveraging digital connectivity.

Goals and Objectives

The overall goal is to develop new functionality that engages the consumer with the product in a new way. Information will be provided about the product and its condition but potentially also by the consumer. It will be processed and adequate reaction will be executed.

Potential Approaches

- Affordable, cheap and scalable digital technologies and new digital interfaces that can enhance consumers' engagement with the packaging & rise awareness about its sustainability and nutrition story, allowing more detailed information than on the pack.
- Intelligent solutions at different interfaces in the product packaging value chain.
- Intelligent packaging solutions that can transform product offering to the consumer.
- Packaging that allows extended interaction in the home environment, that can smartly communicate with the home appliances (for example the food cabinet or the refrigerator) to provide additional information to the consumer.
- Packaging that registers consumer preferences/habits in home/on shelf. The information will be stored in a cloud database and used for benchmarking strategies.
- Packaging that communicates actively with manufacturing and distribution systems and can register data to monitor quality in real time.

Key Performance Indicators

- Technologies that are relevant and directly applicable to business end use.
- Technology must be quick and easy to access and application by the consumer intuitive.
- Technology must be affordable and deployable at large scale.
- Technology must be compatible with packaging materials and formats and should be food application safe.
- Technology must be compatible with recycling packaging.

3.2.6. [Forerunner Project] Foods for Tomorrow: New Concepts and Technologies to Assure Consumer Health and Wellbeing

Introduction and Background

Foods for tomorrow have several requirements. On the one hand, there is an urgent need for food produced with a more favourable carbon footprint and improved productivity to balance out the climate change induced reduction of farmland. On the other hand, food is required which supplies optimal nutrition depending on age, gender and genotype. Producing food in the current way cannot supply a population of 9 billion people without increasing the average temperature by additional 1-2 °C. Beside the carbon footprint, today one already notes effects of the climate change, resulting in the loss of farmland and/or the need of increased need of water and pesticide use

New approaches for sourcing, processing, manufacture and delivery systems for foods and food ingredients are constantly on the rise. These may be specifically intended to add or enhance nutrition and health benefits, to improve the nutrition status and/or be for cost savings or reduced environmental impact. In addition, they may also target global challenges such as the increase of the world population, the decrease in land for food production (e.g. desertification) and the climate change. The desire for more alternative or efficient and sustainable food supply systems drives the interest in alternative raw materials, improved processing (with regard to resource inputs and losses), and efficient (re-)use of waste streams. All of these may have beneficial or adverse effects on the presence, retention, behaviour and functionality of nutrients and other health-relevant components. Nutrition goes far beyond the need to supply just calories. The economic and consumer benefits of future innovation will be supported by research ensuring that the nutritional impact of newly introduced materials and treatments are understood and managed, and that new opportunities to improve the nutritional quality of foods are identified and exploited. Food finally has to be delicious and enjoyable, it not only nurtures the body, it nurtures the soul, too. Europe provides a wide variety of foods. The trend of localization of food within a global society providing local tastes, textures and flavours and ensuring a safe and sustainable supply will be crucial.

Goals and Objectives

Assess and maximize the potential health benefits of future foods and food materials as related to new processing methods in order to:

- Characterize the nutritional value of new or alternative nutrient sources.
- Develop new manufacturing approaches intended to help retain or enhance nutritional qualities.
- Improve prediction of potential nutritional implications of alternative sourcing and processing methods (e.g. implemented to improve sustainability and affordability).
- Increase the value of waste streams by characterizing and validating nutritionally beneficial components.
- Ensure that new food processing approaches will be viewed as transparent and trustworthy by consumers.
- Develop scientifically sound methods for assessing the broad sustainability performance in a systems perspective.

Rationale and Significance

Innovations in sourcing, processing, manufacture and delivery of foods and food ingredients offer a wide range of benefits to agriculture, food industry, individual consumers, and society in general. The ability to successfully exploit these new approaches to deliver improved taste, texture and health attributes with reduced costs and environmental impact will be crucial to maintain a globally competitive and sustainable food industry, while contributing to improved health and well-being in Europe and to answer global challenges related to climate changes and a growing population. Consumer's role in the supply chain has been identified as crucial in improving healthy choices and achieving sustainability goals, with the acknowledgement of the trade-offs between "prosocial" versus "proself" drivers of sustainable and health related attitudes.

Potential Approaches

- Identify potential sources of food, novel food with added health functionality, e.g. from waste streams and by-products.
- Evaluate current and new food sourcing and processing approaches.
- Develop alternative processing approaches, e.g. extraction, modification, fermentation, and processing aids, e.g. enzymes, to enhance the design/production and consumer acceptance of desired nutritional functionalities, e.g. those resulting from specific dietary fibres, new protein sources, nutrient-dense foods, less-energy dense foods, reduce the risk of food intolerance and allergy, etc.
- Improved understanding of societal acceptance and demand of new food sources for a healthier and more sustainable food chain. Barriers to and opportunities of the use of new food sources will be explored.
- Characterize the nutritional attributes of future foods/ingredients/raw materials derived from alternative food, protein and ingredient sources (e.g. algae, insects, etc.), extraction/isolation and production methods, or global regions (i.e., not traditional to Europe).
- Assess and develop/validate improved predictive models for effects of (new) processing methods on retention and transformation of nutrients, and impact on the digestion and bioavailabilities of micro- and macronutrients, and physiological effects.
- Utilize the already available data sources by applying adequate models and archiving methods.
- Analyse the effects of the systems sustainability induced by novel raw materials and processing, thereby considering the dynamics in the supply chain.

Key Performance Indicators

- Standardized approaches and methodologies to characterize nutritional attributes of outcomes / raw material / foods generated by using new food sources and new processing.
- Validated improved predictive models for effects of (new) processing methods on the retention and transformation of nutrients, and impact on the digestion and bioavailability of micro- and macronutrients, and physiological effects.
- Consumer acceptance of new and alternative food sources including the valorisation of waste streams.
- Validated methods for evaluating the environmental implications of effects of large-scale changes in the supply chain.

3.3. R&I Target 3: Developing a More Flexible, Dynamic and Sustainable Food System

Aim. In our future society, good and healthy food should be available to everyone, while making sure that our Earth can remain healthy and even recover from current strains on the environment. For this, we need to make much more effective use of all that we have, and we need to do it the right way to provide healthy, safe and wholesome foods, and not deplete any specific resource.

R&I target 3 is about achieving this goal by combining the exploration and use of new sources for our food and making sure that our future foods are as safe and healthy as they are, or even better. For this, four key areas have been defined that deserve priority: (i) the quest for alternative raw materials for making good foods, (ii) integrated food safety over the whole chain, (iii) better understanding the nature and role of both the internal food matrix structure, and (iv) the package, which ensures the integrity of the food product, should become much more environmentally benign and open to closure of the cycle of raw materials.

Implementation.

It's All Food: Alternative Food Sources. We are used to prepare our foods from plants – seeds, roots and tubers, leaves – and animals – mostly pork, poultry, beef and fish but in fact many more. Great foods are made from these resources, and these will continue to be major raw materials. However, to feed the world, we cannot rely on only these sources. We will need to diversify and explore other sources of good foods. Fortunately, Nature provides many more sources of foods. We may consider sources that are positioned earlier in the natural food chain, such as micro-organisms, algae, seaweeds, but also terrestrial non-chordate phyla such as molluscs and insects, but also sources much later in the food chain, such as (food) waste and side streams. Fermentation may be used to convert these streams into high-quality sources that can then be used either for cattle feed, or directly into human feed. By doing this, the capacity for providing sufficient quality food will be greatly enhanced, while at the same time the footprint in terms of CO_2, energy, water, land use or any other indicator will be significantly reduced.

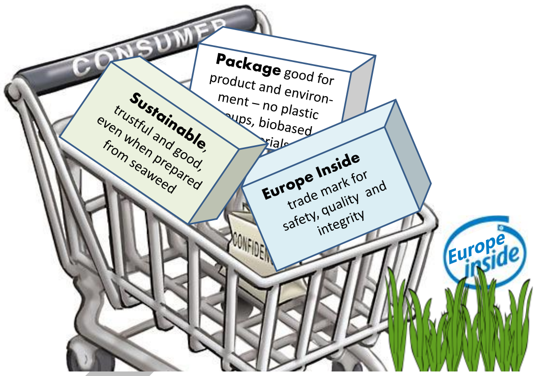
Getting It Right: Integrated Food Safety as a Unique Selling Point. In any future scenario, the safety of our foods should never be compromised. Safe, reliable foods are essential for ensuring a healthy diet, avoiding the adverse effects of any illness borne from foods, but also to ensure consumer trust. Already, European foods are often preferred in other areas, because of the virtual guarantee of their safety. In the future, with the trend towards milder processing and the use of a diversified portfolio of raw materials, but also with a greying population that will become more vulnerable to food-borne complications, the assurance of overall safety, integrity and wholesomeness is essential. Therefore, a programme will be created that aims at the assurance of integrated food safety and food quality over the whole food system. This programme will take into account the implications of the emergence of new raw materials, new and milder processing methods, and new business models (e.g., having many smaller producers selling to individual consumers through the internet).

The Matrix Matters: Food Structure for Better Health. In our quest for healthier foods, industries and academia have mostly looked towards the metabolic role of individual ingredients or even molecules. However, there is overwhelming evidence that this metabolic role strongly depends not only on the composition of our food, but perhaps even stronger on the exact structure of the food. Some micronutrients are ineffective when added to but very effective when naturally present in our food. The reverse also occurs. Even macronutrient availability is strongly dependent on the structure in which it is consumed. This is even more so in more vulnerable consumer groups: infants, elderly people, and people suffering from a disease. In some cases, over-nutrition leading to overweight and obesity is directly related to insufficient recognition of the importance of the food matrix, and the satiety that a well-structured food provides. The result is that a significant step can be made towards the healthiness of our foods, but also towards the efficiency with which we use our resources to feed ourselves, the latter by better understanding and using the matrix of our foods. The challenge is therefore to investigate the exact structure and fate of foods during digestion. This is to make sure our foods deliver good availability of micronutrients, provide adequate satiety to prevent over-intake, and reduce or even eliminate the occurrence of adverse effects.

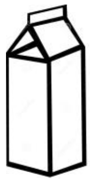
Coming Full Circle: Towards Sustainable Packaging Systems. An essential part of the overall structure of a food product is its package. It provides integrity by making sure that the consumer gets what the label indicates. It also provides safety and stability by avoiding contamination, and enhancing the shelf life (by e.g., modification of the atmosphere in the package), and it contributes to the decision of the consumer to purchase that particular product via the communication on the package. Unfortunately, food packaging contributes significantly to the world's environmental problems. The most often used material is non-biodegradable plastics, which can be incinerated but may also end up in the environment and contribute to the 'plastic soup' in the oceans. Other parts may be of metal. Since these are also discarded, all efforts to produce these materials are ultimately wasted. Thus, a programme will be initiated that will develop novel packaging solutions for the distribution and use of food products that significantly increase the environmental performance of the food systems. While this may be through further developing existing materials, it should certainly work towards more bio-based packaging concepts. New ways and means should be explored to increase the circularity, which include recycling as well as reuse. This will not only include packaging concepts for existing types of products, but will also consider packaging of new types of product creation and distribution, such as through 3D printing, in-store manufacturing and drone delivery through air. In addition to this, significant work will be done to better understand and quantify the fate of packaging materials, in direct relation to their primary role and performance as packaging materials.

Impact.

A successful execution of this research and innovation target will lead to a world in which there is less stress on our environment by spreading the use of Nature over many more sources and one in which European food is recognised as being completely reliable. This trust may make people open to trying out new products and products made from new raw materials. Be the prime trusted region in the world for innovative, sustainable, tasty and healthy food!



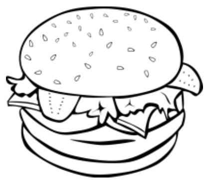
Can you imagine?



The milk you bought today:
made from seaweed,
healthy from its PUFAs, and
the package is from sugar beet pulp!

If you discard it, the carton actually re-fertilises the soil. Many people collect them to use them in their garden....

Can you imagine?



A new premium burger, made with fermentation from side stream from lupine, and it tastes great!
In fact, it is also quite healthy.

And it's European,
so we know it's good.

Can you imagine?

You just looked into your tablet for a new recipe for your 3D food printer. Nice, the package of the ingredients is an ingredient by itself – no waste!

And it comes from the EU, I know it will be safe, so I'm happy to try it out.

3.3.1. Getting It Right: Integrated Food Safety as a Unique Selling Point

Introduction and Background

Biology has seen a revolution with the introduction of cutting-edge technologies in the field of “Omics”. The ability to rapidly and relatively cheaply decipher entire genome sequences, complemented by the ability to map the metagenome of microorganisms, holds the promise of significant advances in our understanding of microbial ecologies. Microbiologists can now uncover in great detail functional metabolic networks in their entirety – not only in single species of microorganisms, but indeed in entire communities.

The application of these “omics” technologies and associated powerful computing capability creates tremendous volumes of sequence data that need to be analysed. Relevant composition and environmental data is also constantly generated across the food chain in the context of current quality and safety management schemes. New and unforeseen levels of data will be available as a result of more direct interaction with consumers who will have food products that communicate through intelligent interfaces included for example in packaging systems and mobile devices. Altogether, these and other data sources could generate a seamless picture of the micro-ecology across the entire food system which enhances food safety and quality. This big data approach to food safety however requires data to be rapidly analysed and cross-correlated in order to translate them into useful and relevant biological insights, which could then be applied to develop effective interventions or control strategies.

Within the food safety and quality area, there is great potential for the generation and utilization of big data to obtain new biological insights. food safety and quality systems are based on a sound scientific base of risk assessment of both microbiological and chemical (toxicological) contaminants. More reliable risk assessments lead to better approaches to mitigation and/or elimination of risks.

Consumer demand for safe and stable foods has not truly changed. In fact, the high quality and safety standards of the European food supply are a characteristic that provides a substantial competitive advantage. However, there is now a pressing need to develop foods that are more mildly processed to retain key organoleptic and functional (e.g., health-enhancing and nutritional) properties, and foods that have been sourced and processed sustainably. From a microbiology point of view, this means a shift towards a combinatorial or hurdle approach to preservation. This is a holistic approach covering the entire farm to table continuum.

Microbiome techniques and approaches enhanced by data characterizing the various micro environments will allow a much more detailed understanding of microbial behaviour and identification of metabolic and regulatory networks in communities that could reveal potential targets for control. This is critical to a hurdle approach where the microorganisms and their environments (the food matrix, processing, storage and distribution environments) are key elements to determining the efficacy of the preservation approach. Such modern data-driven concepts would also create the basis for scenario studies that could support foresight exercises to anticipate new risks.

Advances in genomics and epigenetics have allowed toxicology and the assessment of chemical safety in humans to move away from whole-animal deterministic approaches to one requiring understanding mechanisms of toxicity and human relevance. Considering the potential impact of big data and their translation into biologically-relevant insights, the value of a research program in this area becomes obvious.

Goals and Objectives

To advance this field, a number of different objectives should be systematically pursued:

- Exploit the potential of big data analytics to develop deep insights into microbiological and chemical (toxicological) contaminants and their behaviour across the food system for risk assessment, control and foresight purposes.
- Apply omics technologies and big data analytics to
    - identify potential targets for preservation,
    - develop enhanced predictive models on growth and survival,
    - develop next-generation risk assessment and mitigation protocols to assure food safety & stability, and
    - develop rapid, unambiguous and relevant identification methods for microbiological contaminants to reduce or contain the impact of incidents.
- Develop a science and technology infrastructure (networked and coordinated information technology and microbiology capabilities and skills) that will position the European food industry as leader in the use and application of big data analytics as it applied to food safety and quality.

Potential Approaches

- Fund compelling strategic research programs that use omics technologies in combination with a more deliberate exploitation of big data analytics.
- Develop a strategic information technology- microbiology ecosystem (looking outside the box) through collaborations with companies and institutions that have the "new" skills and resources necessary. Partners will include enterprises, research institutes and universities having both the scientific computing expertise to help generate and interpret the data, but also the ability to generate and collect omics, chemical safety, and consumer data.
- Participate and influence appropriate consortia that will drive progress and standardization, e.g., the COMPARE Consortium on Genome Sequencing of infectious pathogens.
- Establish a 'Virtual Centre for the Food Microbiome and Foodomics'. Such a virtual centre will boost progress in all fields of food related research with the attendant reduction of costs that such collaborative initiatives offer.

Key Performance Indicators

- A decrease in the number of foodborne disease incidences.
- A measurable decrease in food waste (or a measurable efficiency increase of the food system due to less food being lost due to microbial spoilage).
- An increase in the availability of "milder" processed food products.
- Availability of new reliable, predictive models to forecast risk areas and hazard points.

3.3.2. The Matrix Matters: Food Structure for Better Health

Introduction and Background

Many NCDs that plague our world are related to poor diets. A first point of concern is the global obesity epidemic, where excessive caloric intake is often coupled to (selective) under-nutrition. However, even when the caloric intake is appropriate, nutritional profiles are rarely optimal. In addition, the Western world is faced with an aging population. This poses high and often specific challenges on foods and the raw materials they consist of. On top of these food-derived aspects, which already challenge the European health care budgets, there is also a growing consumer awareness of the possible role of food as a direct source of health.

In a more technical sense, these challenges can be understood as a lack of intake and/or (bio) availability of key nutrients, suboptimal profiles of fats, carbohydrates (including fibres), proteins, as well as the over-abundance of high caloric/low satiety foods in general. More balanced diets generally can lead to better health and higher quality of life. In this context, increasing recognition is given to the role of the food matrix and its interdependency with factors such as bioavailability, gut microbiota and the health beneficial bioactive substances themselves.

Simply adding beneficial ingredients is often insufficient due to the key role the food matrix plays in making specific ingredients either available or unavailable (the latter in the case of caloric control) to our digestive system. Primary processing plays a key role as a means to preserve naturally occurring health beneficial raw material components into matrices tailored for the concomitant final food products incorporating the food ingredients.

The more deliberate creation of food structures that maintain the nutritional function of ingredients will ensure that uptake is more efficient, and that ingredients have indeed the desired health effects. This may for example be done by incorporation in specific matrix phases and substructures, by encapsulation, by complexation/chelation, or by other mechanisms that render the components more bioavailable. Here, primary and food processing can both play a key role in making nutrients more or less available, thus enabling a better match between food and metabolic needs.

Goals and Objectives

New health beneficial ingredients and ingredient clusters will be developed. Thus, bioactives providing enhanced health functionalities will become available. The creation of such functionalities will be intimately linked with an optimal integration in the (raw material) carrier matrix during processing. The following four objectives will be addressed by a concerted effort of several partners, all concentrating on different primary processing steps combined with specific raw materials:

- Food structures for optimal satiety and nutrient uptake will be developed. Based on a fundamental understanding of the disassembly of food matrices in the digestive tract, optimal structures for enhanced satiety and nutrient uptake will be developed and scaled-up.
- New technological approaches to better design matrix structures and compositions for the explicit goal of a health benefit optimization will be developed.
- Food matrices and encapsulation techniques that feature the appropriate interaction with individual micronutrients will be developed to optimize e.g. bioavailability. Conversely, the uptake of substances that are detrimental will be minimized.
- The generation of health-adverse co-products created during processing will be reduced.

Rationale and Significance

The actual health effects of functional ingredients greatly depend on the matrix in which they are embedded. For example, both the type and form of complexation/chelation of iron on the one hand and the matrix in which it is embedded are of great importance to its bioavailability. The same holds for many other micronutrients. Generating a basic understanding of the molecular mechanisms/interactions of food matrices in the digestive tract is of vital importance and strong links and iterative developmental steps will support the prosperous development of health promoting food ingredients.

Potential Approaches

Scientific approach. The scientific contribution of this action will be in terms of novel processing and self-assembly concepts to create hierarchically organized multiphase food structures that facilitate the physiological action of various functional ingredients. A proof of principle at the bench-top/pilot plant scale is intended. At the same time, new analytical and data processing capabilities may have to be developed aimed at characterizing and optimizing such structures, compounds and processes. This work is also expected to deliver samples of health beneficial substances in appropriate matrices for studying and optimizing bio-availability for the human metabolism.

Industrial approach. Ingredient suppliers will be active players in the development of new structuring and processing approaches to create functional and acceptable food matrices. A close collaboration with both the primary producers and product manufacturers is needed to make this structure-based health approach economically viable. Scale-up expertise in processing, an understanding of economic and regulatory viability, and a demonstration of in-product feasibility and performance are needed.

Key Performance Indicators

- Number of processes and structuring technologies created or optimized (scale-up to at least pilot plant level).
- Number of raw materials and raw material clusters used.
- Changes in key nutritional and sensory indicators as a result of food matrix design (e.g. bioavailability, satiety).

Impact

- Consumer perceived health benefits due to reduced negative impact of primary processing, optimized bio-availability and enhanced health active substances,
- Consumer preferred food options enabling a lower caloric intake, thus facilitating a healthier lifestyle,
- Increased pool of skilled and knowledgeable European food processing engineers.
- Europe as a food brand: revenues from export of food products and technologies.

3.3.3. Coming Full Circle: Towards Sustainable Packaging Systems

Introduction and Background

The primary role of food packaging is to contain products and to avoid damage resulting from transportation and storage. Package also ensures microbiological food safety and is a barrier against access by unwanted substances that can degrade the product (oxygen, chemical migrants), and against loss of e.g. aroma or moisture. Packaging typically also contains a lot of information relevant for the consumer (such as ingredients, nutrition, and content of potential allergenic compounds, shelf life, handling and preparation) and the supply chain players. At the same time, packaging is often perceived as generating unnecessary waste and polluting the environment. However, efforts to optimize packaging can be detrimental to the environment, particularly if they fail to properly protect the product and thereby generate more food losses and waste. Therefore, packaging solutions must be looked at as part of the food supply system and their effectiveness must be measured in this holistic context. Consumption patterns and distribution channels change drastically due to increasing numbers of single and small households, the increasing demand for healthy, fresh and sustainable foods, increased online shopping and the use of other new channels. As a consequence, packaging solutions must be adapted to new trends in order to yield best performance in protecting food with minimal use of resources.

Goals and Objectives

The overall goal is to develop novel packaging solutions for the distribution and use of food products that increase the environmental performance of the food systems (life cycle analysis). In this research action, new ways and means to increase the circularity, that is to increase recycle or reuse opportunities, will be developed. Currently, there are technological, economical, and regulatory hurdles that need to be addressed simultaneously to decrease the loss of packaging materials into waste streams. Consumer acceptance of reuse solutions and options should be studied to assure that the new technical solutions will not fail in the market because they are ultimately rejected.

Potential Approaches

- Develop technologies to better collect, valorise and/or recycle packaging materials at end of life (e.g. close-loop recycling technologies, mechanical recycling, up-cycling, down-cycling).
- Generate packaging concepts that can reduce food waste after first opening (e.g. by enabling complete emptying, or by better protecting left-overs in the original pack to increase secondary shelf-life there by optimizing and enhancing re-closing functions).
- Develop packaging materials, technologies and concepts with the right functionality and delivering superior environmental performance on the total life-cycle. Approaches are needed that generate materials of which less is needed and that last longer. Examples include nanomaterials, composites, down-gauging films, and solutions addressing the challenges imposed by the upcoming new ways of distributing, buying and using (e.g. in store manufacture, 3D printing, air delivery via drones).
- Education: research ways to educate consumers and more effectively engage with them in the recovery and revalorization process.
- Increase the range of economically feasible, high performance bio-based packaging materials (ideally from sustainably managed renewable resources that do not directly compete with food).
- Develop new multidimensional tools and methods that allow for package optimization considering packaging performance in terms of e.g. shelf life, protection, thermo-mechanical stability, process ability.

Key Performance Indicators

- Reduced food losses and waste.
- Reduced leakage of packaging into environment.
- Reduced packaging-driven environmental impact.
- Improved recyclability of material and infrastructure.

- Decreased proportion of packaging materials not re-cycled or valorised.

3.3.4. It's All Food: Alternative Food Sources

Introduction and Background

The availability of food from environmentally-sustainable sources is a pre-requisite for feeding a growing population and preserving resources. One way to obtain more food is to make better use of the diversity that Nature offers. New raw materials and processes to convert them into food products/ingredients need to be identified. A key challenge for future food security is meeting demand for sustainable sourcing of the main food building blocks being proteins, (healthy) lipids and (healthy) carbohydrates (e.g. dietary fibre).

While we harvest food from the sea, we mainly only harvest the organisms that are near or at the top of the food chain. The ultimate ecological impact of fishing these organisms is therefore perhaps hundreds of times larger than just catching those fish. We can also harvest the organisms that are near or at the bottom of the food chain, such as algae, seaweed and krill. These are present in abundance and with careful management a significant harvest could be realized. We can also make better use of the terrestrial non-chordate phyla (insects, molluscs) which typically grow very fast, and efficiently metabolize their plant food into animal biomass. In addition, we can harvest these not from 'wild' stocks but rather cultivate them in terrestrial or marine farms, which, if carefully managed allows for concentrated growth and controlled quality while limiting environmental footprint.

A third source of food remains also relatively untapped, i.e. food grown directly from waste, or manufactured through direct use of side streams. Our society and industries produce very large quantities of waste and side streams which are now either discarded, burned, or sometimes partially re-used, composted and combusted. However, we can also convert the organic parts into food, for example by fermentation using novel fungi, food-grade bacteria and yeasts, and further refining. In a world with ever larger metropoles, it would be attractive to re-use wastes to grow food that is also used in the same metropole, thus mitigating the logistics and the depletion of the surrounding countryside. Aside from growth practices, biotechnological and enzyme approaches can be used to convert non-food materials into food. Overall, the various approaches could alleviate raw material shortages that are already occurring and therefore increase food security across Europe.

Goals and Objectives

In this action we strive to reduce the overall environmental impact and the reliance on imports, and to improve the quality of foods by introducing a host of new raw materials for the production of food.

- Finding ways to process lower organisms (microorganisms, algae, insects, molluscs and krill) efficiently into high-quality food ingredients. This requires overcoming a number of important technical and cultural (e.g. under what conditions will consumers consider and even choose food made from these lower organisms) hurdles.

- Finding ways to efficiently grow micro-organisms (fungi, bacteria, archaea, yeasts, etc.) on waste and harvest those for production of food ingredients.
- Finding ways to overcome cultural hurdles that may inhibit adoption of use of alternative raw materials in food products.
- Finding new ways to utilize process side streams and valorise them by further processing (purification, fermentation, enzyme or physicochemical catalysis). In that way one can make best possible use of the complete starting raw material. The efficient removal of unwanted components sometimes concentrated in side streams, as well as safety and regulatory considerations will be important points to address.
- In order to use the ingredients derived from new raw material sources, it is imperative to develop an in depth multi-scale understanding of their functionality and nutritional quality and how to tailor their functionality for use in complex foods. This includes multi-scale understanding of ingredient functionality (gelling, foaming, emulsification etc.), the study of interactions (molecular) between different ingredients.

Rationale and Significance

The use of lower organisms and waste as raw material to produce new food is more efficient than the use of higher organisms, such as our current C5/C6 plant sources, and mammal and avian species for food. The use of lower organisms can be a big step in increasing the efficiency of food production. Second, the composition of these organisms may be attractive from a nutritional perspective. Insects have an excellent protein composition, while sea organisms contain oils and other nutritionally important components. Using waste as raw material may not only help in the production of food but also in reducing the total amount of waste created in urban environments. Also, it may shift food production partly into the cities and bring food production closer to the individual consumer (who could even become a local producer). It thus may help create a different type of society.

Potential Approaches

Industrial approach. Usage of new raw materials will only be successful if there is a market for them. However, a market can only be developed when the supply is guaranteed. This system lock-in can only be broken by a concerted action of ingredient suppliers and food producers. Therefore, a consortium will be built around exploring a limited number of possible new raw materials to further refine them into food ingredients.

Innovative approach. While many potential raw materials have an interesting chemical composition, new processes will need to be developed to recover value components in the most effective way. Due to the involved processes and raw materials, the resulting ingredients will likely be novel and will therefore need a thorough characterization in order to evaluate their potential as food ingredients and ensure that they can be approved.

Scientific approach. The identification and mapping of new raw materials is a key element. A thorough understanding of possible raw material sources, their composition, nutritional quality and availability must be built. New fractionation and/or enrichment or elimination processes will need to be developed. This will help focusing on the most promising materials and allow a more targeted approach. Moreover, as consumers may not always accept new raw materials as source of their food, consumer research is needed to understand what influences acceptance by consumers of new raw materials and production processes.,

Key Performance Indicators

- Creation of intellectual property and new businesses.
- Number of viable new raw material identified.
- Economic feasibility demonstrated.
- Consumer acceptance of new raw materials and production processes has been assessed.

Impact

- Percentage of foods consumed derived from/containing new ingredients.
- Growth in employment, e.g. new jobs created in cultivating, harvesting new raw materials.
- Lower dependence on raw material imports.
- New consumer food experiences.

3.3.5. Check It: Next Generation Strategies for Food Safety Assessment

Background and Rationale

The capacity to assess the risk that a food-borne hazard of any type presents to the consumer is fundamental to those charged with governing the food chain. Risk is the basis for taking intervention measures and applying resources across the food system. In the case of chemical hazards, the variety of potentially toxic residues detectable in food is continuously increasing as a consequence of industrial development, new agricultural practices, environmental pollution, rapidly evolving analytical procedures and climate change. In recent years, toxicology and the assessment of chemical safety in humans has undergone a paradigm shift in approach. One has moved away from a science based solely on whole-animal deterministic approaches to one based on understanding the underlying mechanisms of toxicity and relevance to human metabolism. Factors contributing to this shift include rapid advances in science (particularly in genomics and epigenetics), advances in technology (analytical, computational toxicology, systems biology, bioinformatics) and the emergence of big data. The scientific value of data generated with animal tests is under discussion while at the same time society is demanding the transition to non-animal assessment methods.

This new "toxicology in the 21st Century" approach was heralded by the US National Research Council (NRC) in 2007, and the OECD has subsequently provided guidance on developing and assessment of adverse outcome pathways. As a consequence, new strategies are needed to meet the societal demands on reducing animal tests on human foods, for the safety assessment of food matrices and ingredients.

Microbial risk assessment, whilst not as mature as that applied to chemical hazards, is still the science base of the governance of modern microbial food safety. Microbial hazards constantly challenge the safety of the modern food chain. New threats appear from known hazards in unexpected situations and organisms previously unrecognized as hazards reveal themselves to be pathogenic. Many of the factors that change the landscape of chemical risk assessment also alter the possibilities for undertaking risk assessments on microbial hazards. This is certainly so for genomic, systems biology and bioinformatics developments. Parallel to the possibilities in toxicology, the incredible discrimination that these approaches permit, when applied to the interactions between the microbe and the human (pathogenicity and dose-response), opens up the possibility of reducing greatly the high level of uncertainty caused by the current “taxonomical” approach of attributing pathogenicity to all organisms that share a name.

The application of these approaches to microbes in a food environment (or an environment’s metagenome) together with the constant gathering and analysis of microbiologically relevant compositional and environmental data which happens as a matter of course in the modern food chain, will generate a seamless picture of the micro-ecology of the food chain. This will permit new ways of approaching key aspects of exposure assessment in the risk assessment process.

Goals and Objectives

The overarching goal is to develop an integrated strategy for food safety assessment adopting a ‘from farm to fork’ approach which includes monitoring strategies for the safety of food throughout the food chain. It will include the comprehensive assessment of food safety, quality, and traceability as a whole.

- An open and transparent culture of food will be created. It will guarantee safety amongst all stakeholders and confidence with consumers.
- Sustainability will be addressed within the context of food safety.
- A platform trusted by the food industry and consumers for safety assurance of foods will be built without the need for animal testing. Doing so will deepens the insight in the underlying mechanisms and phenomena.
- Genomic approaches will be exploited to drive microbial safety assessments to new levels based on deeper and more strain specific knowledge of human-microbe interaction and a fuller understanding of the micro-ecologies of the food chain.

Potential Approaches

- All actors work together to assure the practical implementation of the new methods and procedures that will be developed.

- Detailed research into the way consumers perceive risk and food safety. Integration of the findings in the new methods and procedures. Involvement and engagement of consumers in methods and procedures.
- New and better methods to assess chemical safety especially in complex food matrices. Flexibility and innovation is required to deal with new challenges such as the allergenicity potential of new ingredients such as new and modified proteins. This may include miniaturization of analytical systems (labs-on-a-chip), reduction of sample preparation for fast screening methods, and new analytical methods to detect and characterize nanomaterials.
- Bringing together all of the chemical safety directed approaches to develop a roadmap of research with the explicit objective of reducing and eventually replacing animal testing.
- Working with the full complexity of data (and subsequently models) - analytical, food chain, consumer and public health generated - in an overall integrated approach to safety assessment.
- Big data' enable monitoring' the safety of the food in the market place using post launch monitoring approaches. Combination with machine learning methods will allow leaps in our understanding of causes of a breach of safety.

Key Performance Indicators

- Quicker, less expensive routes for the assurance of food safety.
- A better understanding of human metabolic pathways and interactions that will allow predicting the safety of a food or new components. This knowledge will be operationalized into *in silico* models.
- New methods that will enable the minimization or even elimination of animal testing without compromising on food safety.
- Integrated strategies in foodomics, including advanced analytical techniques and bioinformatics which will integrate food safety assessment into a better overall understanding of nutrition.
- More precise methods for the microbiological safety assessment of foods based on the real risk presented by an organism and not only its wider taxonomic status.

3.3.6. Simply Natural: Towards Less Refined, More Natural Food Ingredients

Introduction and Background

In the past decades, the production of ingredients has become highly optimized to meet purchaser demands. Plant-based ingredients such as sugars, proteins, starches and many other ingredients, are often highly purified, which makes them universally applicable in many products. There is, however, an opposing consumer pull for natural ingredients due to perceived beneficial effects on health. Concerns about “E numbers” and an overall drive towards increased transparency of the food system create demand for new, less refined (i.e. more clean label) ingredients. In addition, fractionation and purification approaches also contribute to environmental impacts of the food system, having an effect on sustainable use of raw materials, energy and water. However, while many less refined ingredients have excellent properties, they often differ from those of highly refined ingredients. Innovation in the use of less refined ingredients to allow manufacture of healthy, tasty and attractive products for consumers is therefore needed. These may include tailored food for specific consumer groups, conventional products, but may also be ingredients that facilitate the production of very new products (e.g. components that allow foods to be 3D-printed).

Modern insight in the properties and structure of the raw materials enables development of a new generation of food ingredients by tailored fractionation of the raw material into classes, which are not pure isolates, but which consist of mixtures of structures and components with very good functionalities, both in a technical, and in a nutritional sense. In addition, increased understanding of complex raw material matrices will enable developing smarter processes with an integral approach to more holistically use raw materials. This is in opposition to the conventional approach which divides the raw material into main streams used for products and side streams being discarded or used for something else (Fig.7). For example, an impure plant protein fraction obtained by concentrated wet fractionation is superior to a pure isolate in emulsion stabilization and pH robustness. Extracting complete oil bodies with a mild aqueous extraction yields a vegetable oil that is well protected by its natural membrane, giving it chemical stability of several months. With it, stable emulsion products can be manufactured without the need of any stabilizer. Using such types of new, more complex structured and composed functional ingredients may give opportunities for cleaner label products, with less need for additives having E-numbers. As a side benefit, this could minimize risks for the increasing group of consumers that are subject to food allergies

Production methods tailored to employ the least necessary level of processing may offer improvements in environmental sustainability as well as in production costs since raw materials do not have to be completely broken down and then built back up to form complex foods. At the same time, this will enable manufacture of products that are less refined, because the ingredients for a significant part contain fibre and other components. Such products may have superior properties in terms of stability, since biological systems designed to protect the raw materials from degradation may still be intact.

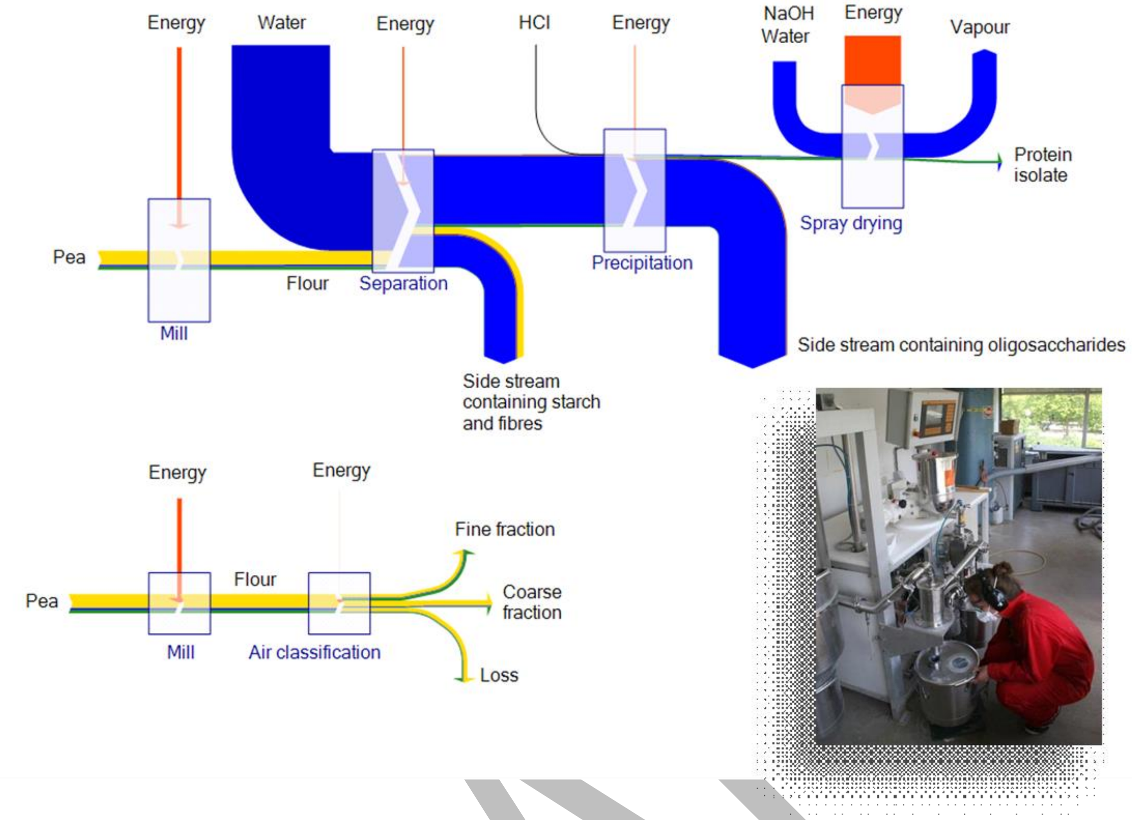


Figure 7. Illustration of impact of raw material fractionation on energy consumption and resulting possible food ingredient grades. Comparison of the resources needed in conventional wet fractionation of pea (upper diagram), and dry fractionation by air classification or other dry separation techniques (lower diagram; the two diagrams have the same scale) for separation of flour particles with varying protein contents. Fractions still contain 20 – 40 weight% fibre and many micronutrients and possess adverse functional properties regarding solubility, thickening effects etc.

Goals and Objectives

This action aims at developing new methods to fractionate food raw materials into functional ingredient classes, without striving for purity at a molecular level. The goal is thus to explore the naturally occurring nutritional and functional properties using minimal or mild processing. To accomplish this, projects will be carried out

- To understand how consumers view “naturalness” and how its perception is linked to characteristics of food origin and processing.
- To understand how the benefits of minimally processed ingredients can be communicated to consumers in a convincing way.
- To develop new methods to prepare minimally processed, highly functional ingredients with only a fraction of the resources needed in conventional ingredient refining and with reduced use of additives and processing aids. Method development will be linked to understanding the impact of using less refined ingredients on the taste and appearance of the food products and may include *in situ* generation of flavours by fermentation. Recent developments in sensory research will be integrated.

- To exemplify how raw material matrix understanding combined with an integral approach to smart processing enables full exploitation of raw materials with overall higher value creation.
- To explore and understand the nature of the interactions in semi-refined ingredients which give rise to their specific properties. Understanding from a molecular to a supramolecular level is needed to identify the decisive parameters for optimal functionality and nutritional value of these ingredients for incorporation into food products.
- To define crop characteristics for optimal processing, thus selecting new cultivars with improved profiles suited for new fractionation methods with respect to separation efficiency or yield.
- To develop scaled down processing solutions to enable more local ingredient sourcing away from global mass production ("glocalization"). Such provenance will be at the heart of establishing naturalness credentials and will build consumer trust through a radically transparent agro-supply chain. Using simple fractionation, e.g. dry separation, one can already separate part of the raw material (e.g. the husks and bran) on the farm, leave valuable soil nutrients on the farm, and only transport the nutritionally valuable part to processing plants, thus lessening soil depletion and reducing the need for transportation and lessening the production of waste.
- To explore food safety aspects of novel processing methodologies, including safety assessment of new processing chains (microbial, allergen and anti-nutritional components) and traceability for local down-scaled processing (semi-refined ingredients).
- To decrease declaration short lists by developing functionally complementary single origin ingredients.
- To explore and understand the attitude of consumers to products made from functional fractions without E-numbers and to find the best way of answering the call of the consumer for cleaner-labelled food and consumer demands for food produced in an environmentally sustainable way.

Rationale and Significance

The European food industry can take a giant leap. Production costs can be significantly lowered, products can contribute to health (and thus, mitigating diet related non-communicable diseases), and the industry can implement a more viable path to food production using a knowledge-based approach to food ingredient classes. The value is not so much in the fraction or the class as such, but mostly in understanding how one should apply it into food products, and how to relate these new properties into products that the consumer wishes to purchase and consume. Thus, this radical, yet realistic action will have far-reaching consequences. It will give the European food industry a significant competitive advantage, while offering a long-term approach towards improving our health, reducing energy and water consumption, and lowering waste and CO_2 emissions.

Potential Approaches

Industrial approach. Production of new types of ingredients will only be successful if there is a market for them. However, a market can only be developed when the supply is guaranteed and their application is accepted in the market place. This system lock-in can only be broken by a concerted action of readily adaptable/agile ingredient producers, together with some major food producers. A consortium of small, medium and large scale enterprises will be built around exploitation and demonstration of the feasibility of a limited number of less refined ingredients to create an open market for these types of ingredients. When transforming the agro-supply chain care will be taken to address the requirements of more localized production.

Innovative approach. Functionality is a major driver for developing food ingredients that meet market demands. Understanding why and how impure fractions with preserved natural components contribute to better functionality and health beneficial effects will redefine the market for tailored and sustainable food ingredients. The innovation approach will consist of an adaptation of biology-inspired processes supporting the consumer demand for naturalness, thus using e.g. naturally occurring enzyme cascade systems and naturally occurring sources of microorganisms for fermentation. The perception of naturalness and its acceptance will then be studied with consumers or through test markets.

Scientific approach. Research has to be conducted to uncover the reasons for consumers to perceive, appreciate and accept the naturalness of less refined ingredients. This can give direction to the development of specific solutions. The reason for new properties and functionalities exhibited by less refined ingredients is not fully understood. This requires significant research efforts ranging from fundamental to applied, in which colloidal and nanoscale approaches will yield insights into structure - function relationships of biological systems at the relevant size ranges. The action will require an interdisciplinary approach spanning understanding the nature of raw materials from molecular to macroscopic scales, the stability of ingredients once removed from the raw materials, design of optimal fractionation procedures not only during standard food process operations but also during primary processing, potential reconstitution needs, interaction of the new ingredient classes in food matrices, and economic factors. This will allow the food industry as purchasers of the new food ingredients to assess viability. Additional research will then be needed to prove safety and benefits of new ingredients in humans. Moreover, research will be required to understand consumer preferences for products with less E-numbers and more natural ingredients, based on product sensory perception, physiology and social and cultural contexts.

Impacts

- A new class of more natural food ingredients which will support the development of potentially health promoting food based on preservation of natural functionalities and improved possibilities for individualized food and will have a potentially positive impact on public health systems.

- An increased integration of primary producers in the food production chain which will increase the livelihood opportunities of farmers by increasing the value of crops.
- A renewed focus on the functionality derived from many diverging raw material structures will shift agricultural practices towards an increased valuation of crop biodiversity rather than just yield.
- Support for new job creation and job retention in rural areas will be achieved through down scaling of processing methods, which will be of particular importance to Eastern Europe fostering an increased modernization of agro-food chain production methods.
- Consumer trust in the agro-food-industry through generation of a more transparent food system with minimally processed food ingredients and more cleanly labelled food.
- A more sustainable use of raw materials, energy and water, thus positively impacting the environmental effects of food production.

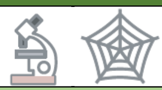
Key Performance Indicators

- Alternative sustainable and biological (natural) processes for producing processed raw materials with equal and/or improved functionalities when compared to their currently available fractionated forms.
- Approval of the above raw materials for use in foods.
- Market releases of raw material structures that allow creating new food properties.

4. Prioritization and Implementation

The table below represented a first recommendation by the ETP on prioritizing action items in the remaining timeline of Horizon 2020. The symbols indicate the nature of the expected impacts from action items.

	Research and knowledge generation
	Networking
	New products / business opportunities

R&I Target 1		Increasing the Engagement and Involvement of Consumers	
2018-2019	Action 1	Improving insights in Consumers	
		Impact: improved consumer engagement and insight; new products aligned with consumer and societal needs.	
	Action 2	Food and Me: Making Food an Activity	
		Impact: better bi-directional communication between consumers and food chain actors; new products and new business opportunities.	
	Action 3	Food Inventors: New Food Production and Delivery Models to Provide Better Access	
		Impact: clear understanding of consumer perceptions and behaviour impacts; novel sustainable business models.	
2019-2020	Action 4	Footprinting of Food: Consumer Engagement in Sustainability	
		Impact: increased sustainability of the food chain; improved consumer engagement; generation of functional open source systems.	
	Action 5	The Smart Food Grid: Modular Food Production and Distribution	
		Impact: novel distribution channels and delivery modes; increased sustainability of the food chain.	
R&I Target 2		**Providing the Basis for a More Personalized and Customized Food Supply**	
2018-2019	Action 1	The Food I Love: Appreciation of Diversity in Food and Eating	
		Impact: understanding and recognition of food appreciation across the EU and its relation to consumption practices; new products and services responding to consumer diversity.	
	Action 2	(Tr)eat Me: Dietary Approaches for the Prevention of Non-Communicable Diseases	
		Impact: decrease in the occurrence of NCDs; dietary recommendations for specific population groups.	
	Action 3	In Silico Food Design: Understanding Food Digestion	
		Impact: increased knowledge about micronutrient digestion; new ingredients targeted to better address malnutrition; minimise the need for animal testing.	

	Action 4	The Ecology Inside Us: Food Meets Gut Microbiome
		Impact: description of the gut ecosystem, the microbiota function and its impact on health; new opportunities for dietary interventions via gut microbiome
2019-2020	Action 5	Packaging 4.0: Intelligent and Communicating Packages
2019-2020		*Impact:* novel intelligent packaging solutions; increased sustainability and operability of the food systems.
2019-2020	Action 6	Forerunner 'Foods for Tomorrow': New Concepts and Technologies to Assure Consumer Health and Wellbeing
2019-2020		*Impact:* improved methodologies to characterize nutritional attributes at different stages and the impact of new processing techniques on them; consumer acceptance of new and alternative food sources; understanding of the effects of large-scale changes in the supply chain
R&I Target 3		Developing a More Flexible, Dynamic and Sustainable Food System
2018-2019	Action 1	Getting It Right: Integrated Food Safety as a Unique Selling Point
2018-2019		*Impact:* less foodborne disease incidences and better forecasting models; decrease in food waste; novel "milder" processed food products.
2018-2019	Action 2	The Matrix Matters: Food Structure for Better Health
2018-2019		*Impact:* optimized bio-availability and enhanced health active substances; new food options with lower caloric intake; increased export of food products and technologies.
2018-2019	Action 3	Coming Full Circle: Towards Sustainable Packaging Systems
2018-2019		*Impact:* Reduced the environmental impact of packaging; improved the environmental performance of the food system.
2018-2019	Action 4	It's All Food: Alternative Food Sources
2018-2019		*Impact:* novel food containing new ingredients; lower dependency on raw material imports; new business opportunities.
2019-2020	Action 5	Check It: Next Generation Strategies for Food Safety Assessment
2019-2020		*Impact:* improved methods for food safety assurance; better prediction the toxicity of new components; minimise the need for animal testing.
2019-2020	Action 6	Simply Natural: Towards Less Refined, More Natural Food Ingredients
2019-2020		Impact: more natural food ingredients; an increased integration of primary producers in the food production chain; empowerment of rural areas; increased consumer trust in the agro-food-industry; less environmental effects of food production; new business opportunities.

Further details on these recommendations, and on specific implementation measures will be published in the forthcoming Implementation action plan (IAP) (Spring 2017).

5. Appendix 1. Related Initiatives in the European Research Area.

The success of the SRIA relies on an effective collaboration with other partners of the European Research Area, coming from sectors such as ICT, manufacturing, energy, transport, nanotechnology, water, agriculture, etc. and with the relevant funding structures. The initiatives and organizations listed below are a non-exhaustive list of the groups the European Food Industry is keen to cooperate with to accomplish the proposed objectives.

5.1. Horizon 2020

Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020) implementing the Innovation Union, a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness.

Seen as a means to drive economic growth and create jobs, Horizon 2020 has the political backing of Europe's leaders and the Members of the European Parliament. By coupling research and innovation, Horizon 2020 is helping to achieve this with its emphasis on excellent science, industrial leadership and tackling societal challenges. The goal is to ensure Europe produces world-class science, removes barriers to innovation and makes it easier for the public and private sectors to work together in delivering innovation.

5.2. Knowledge and Innovation Communities (KICs)

Integrates all three sides of the 'knowledge triangle', i.e. higher education, research and business, in Knowledge and Innovation Communities (KICs), fostering the entire innovation chain – including training and education programmes, reinforcing the journey from research to the market, innovation projects and business incubators. Its goals are, among others, creation of new businesses and new jobs, and the promotion of new skills and entrepreneurial talent in the economy.

The upcoming KIC on food 'Food4Future Sustainable Supply Chain from Resources to Consumers' will be operational from 2017 to 2024.

5.3. European Innovation Partnerships

EIPs promote technology transfer to increase the impact of actions funded under Horizon 2020 by linking them to a broader strategy. The EIP on 'Agricultural Productivity and Sustainability' (EIP-AGRI, launched in February 2012) aims to foster a competitive and sustainable agriculture and forestry sector that "achieves more from less", contributing to ensuring a steady supply of food, feed and biomaterials, and a sustainable management of the natural resources. For achieving this goal, the EIP-AGRI builds bridges between research and practitioners (mainly farmers).

5.4. Scientific Committee for Agricultural Research

The Standing Committee on Agricultural Research (SCAR) was established in 1974 and re-launched in 2005. It is a source of advice on European agricultural and wider bioeconomy research, along with being a major catalyst for the coordination of national research programmes. SCAR currently represents 37 different countries, the members being ministries (or other organizations such as research councils) from all EU Member States, with Candidate and Associated Countries as observers.

In 2016 a SCAR Working Group on Food Systems has been established.

5.5. EU Food Sustainable Consumption and Production Round Table

The EU Food SCP Round Table is an initiative co-chaired by the European Commission and food supply chain partners (European food supply chain, also open to consumer organizations and environmental/nature conservation NGOs). It is supported by the UN Environment Programme and the European Environment Agency.

The aim of the European Food SCP Round Table is to establish the food chain as a major contributor towards sustainable consumption and production in Europe, centred around three main topics in the management of environmental sustainability along the European food chain:

- Identification of scientifically reliable and uniform environmental assessment methodologies for food and drink products, including product category specifications where relevant, considering their significant impacts across the entire product life-cycle
- Identification of suitable communication tools to consumers and other stakeholders, looking at all channels and means of communication
- Promotion of and reporting on continuous environmental improvement along the entire food supply chain and engaging in an open dialogue with its stakeholders

5.6. EU Platform for Diet, Physical Activity and Health

The EU platform for action on diet, physical activity and health is a forum for European-level organisations, ranging from the food industry to consumer protection NGOs, willing to commit to tackling current trends in diet and physical activity. The purpose of this Platform is to provide a common forum for all interested actors at European level (currently 34 members) where they can explain their plans to contribute concretely to the pursuit of healthy nutrition, physical activity and the fight against obesity, and where the outcomes and experience from actors' performance can be reported and reviewed.

The fields for action identified so far by the current actors in the Platform reflect the various experiences of participants: Consumer information (including labelling), education, physical activity promotion, marketing and advertising and composition of foods (i.e. availability of healthy food options, portion sizes).

Related to this initiative there is a **'High Level Group on Nutrition and Physical activity'**, formed by government representatives from all 28 EU member countries and the 2 EFTA countries (Norway, Switzerland). It seeks European solutions to obesity-related health issues by offering an overview of all government policies, helps governments to share policy ideas and improves liaison between governments and the EU platform for diet, physical activity and health, with which they regularly meet.

5.7. FACCE-JPI (Agriculture, Food Security and Climate Change)

FACCE-JPI gathers member states committed to ensuring sustainable food production under climate change while at the same time protecting the environment and natural resources. The actions funded are targeted to achieve a sustainable food security under climate change and an environmentally sustainable growth and intensification of agricultural systems under current and future resource availability. It also aims at assessing and reducing trade-offs between food production, biodiversity and ecosystem services, adapting to climate change throughout the whole food chain and mitigating greenhouse gas. So far, it has launched several actions:

- Modelling European Agriculture with Climate Change for Food Security (MACSUR)
- Knowledge Network Sustainable Intensification (KNSI)
- Sustainable and Resilient agriculture for food and non-food systems (SURPLUS)
- Monitoring and Mitigation of Greenhouse gases from Agri- and Silvi-culture (ERA-GAS)
- Climate Smart Agriculture: Adaptation of agricultural systems in Europe
- Joint Call with the Belmont Forum on Food Security and Land Use Change

5.8. JPI HDHDL (Healthy Diet for a Healthy Life)

JPI HDHL brings together 25 countries that collaborate together to align their research strategies in the area of nutrition and health. It is focused on ensuring that the healthy choice is the easy choice for consumers, on developing high-quality, healthy, safe and sustainable food products and on preventing diet-related, chronic diseases and increasing the quality of life.

Up to date, it has launched several Joint Actions for networking and research projects:

- Knowledge Hub on the DEterminants of DIet and Physical Activity (DEDIPAC)
- Biomarkers for Nutrition and Health (BioNH) (projects funded)
- European Nutritional Phenotype Assessment and Data Sharing Initiative (ENPADASI)
- Intestinal Microbiomics (projects funded)

- Nutrition and Cognitive Function (NutriCog) (projects funded)
- Food Processing for Health (projects funded)
- Malnutrition in the Elderly Knowledge Hub (MaNuEl)

JPI HDHL focuses on the consumption side of the food chain while FACCE-JPI's main focus is on the production side. Nevertheless, both initiatives have a common interest in the impact of climate change on providing a sustainable food supply that has the nutritional requirements to ensure a healthy population.

Besides FACCE and HDHL, the current list of JPIs includes: JPND (Neurodegenerative Diseases), JPI CH (Cultural Heritage), JPI-MYBL (More Years Better Lives), JPIAMR (Antimicrobial Resistance), Water JPI (Water Challenges for a Changing World), JPI Oceans (Healthy and Productive Oceans), JPI Climate (Connecting Climate Knowledge for Europe) and JPI UE (Urban Europe).

5.9. ERA-Nets

ERA-Nets are designed to support public-public partnerships in their preparation and coordination of joint activities as well as Union topping-up of a trans-national call for proposals in the area of research and/or innovation projects, resulting in grants to third parties. Some examples (for a complete list consult this link) of ongoing ERA-Nets are:

- SUSFOOD 2 – Sustainable Food Production and Consumption (upcoming!)
- SusAn – Sustainable Animal Production
- BiodivERsA – Consolidating the European Research Area on biodiversity and ecosystem services
- EUROTRANSBIO (ETB-PRO) – EUROpean programme for TRANS-national R&D&I. cooperations of BIOtech SMEs
- ERA-MBT – Marine Biotechnology ERA-NET
- BiophotonicsPlus – Photonic appliances for life sciences and health

For a list of past ERA-Nets in the Bioeconomy, please refer to this http://www.era-platform.eu/era-nets/

5.10. JTIs established under FP7

JTIs are public-private consortia at EU level, involving industry, research community and public authorities, which are set up to pursue ambitious common research objectives. They address strategic areas where research and innovation are essential to European competitiveness. Most of them have a length of 10 years, were set up within 7PM and nowadays JTI budget depends on the resources allocated by H2020, the European industrial sector and the Member States. There are JTIs in the fields of innovative medicines, fuel cell and hydrogen energy technologies, aeronautics, electronic components and systems and bioeconomy.

The **Joint Undertaking on Bio-based Industries (BBI)** is a public-private partnership aiming at increasing investment in the development of a sustainable bio-based industry sector in Europe. It foresees €3.7 billion investments in bio-based innovation from 2014-2020 (€975 million of EU funds within Horizon 2020 + €2.7 billion of private investments, leveraging capital markets and additional private and public funds). It focuses on feedstock (foster a sustainable biomass supply with increased productivity and building new supply chains), biorefineries (optimise efficient processing through R&D and demonstrate their efficiency and economic viability at large-scale demo/flagship biorefineries) and markets, products and policies (develop markets for bio-based products and optimise policy frameworks)

Innovation Investment Package - total investments (2014-20) (in € millions)

Joint Technology Initiatives			
JTI	**EU (Horizon 2020) + EU Member States (for Electronics only)**	**Industry**	**Total**
Innovative Medicines Initiative 2	€1725	€1725	€3450
Fuel Cells and Hydrogen 2	€700	€700	€1400
Clean Sky 2	€1800	€2250	€4050
Bio-based Industries	€1000	€2800	€3800
Electronic Components and Systems	€1215 (+ €1200 from EU Member States)	€2400	€4815
Total JTIs	*€7640 (€6440 from Horizon 2020 + €1200 from EU Member States)*	*€9 875*	*€17 515*

5.11. Contractual PPPs

In the cPPPs the contractual arrangement specifies an indicative 7 years EU funding and the budget is only committed on an annual basis. The Commission is responsible for implementing the programme, which is governed under the rule of the Commission Framework Programme for Research: Interested organisations form consortia and submit proposals in response to call topics announced annually by the Commission. Following an independent evaluation, a project is assigned a percentage of funding from the European Union with the rest of the funding and resources coming from the members of the project consortium.

Almost all cPPPs are sitting in the LEIT (Leadership in Enabling and Industrial Technologies) pillar, such as:

- **SPIRE (Sustainable Process Industries through Resource and Energy Efficiency)** is dedicated to innovation in resource and energy efficiency and enabled by the process industries. Its objective is to develop the enabling technologies and solutions along the value chain, required to reach long term sustainability for Europe in terms of global competitiveness, ecology and employment. More specifically, SPIRE is addressing three fundamental European challenges: create growth and increase competitiveness, rejuvenate the European process industry and reduce resource and energy inefficiency and the environmental impact of industrial activities. Its research priorities are identified in its roadmap. The private consortium represents more than 130 industrial and research process industry stakeholders from over a dozen countries spread throughout Europe, coming from 8 industry sectors (chemical, steel, engineering, minerals, non-ferrous metals, cement, ceramics, and water).

- **FoF (Factories of the Future)** aims at enabling a more sustainable and a more competitive European industry by supporting European manufacturing enterprises in strengthening their technological base. Its research priorities are identified in its roadmap. The industrial consortium behind FoF was established jointly by the MANUFUTURE ETP and key industrial associations.

Contractual PPPs – indicative budgets (2014-20) (in € millions)

cPPP	EU (Horizon 2020) indicative budget (mio. €)
Factories of the Future	1,150
Energy-efficient Buildings	600
Sustainable Process Industry	900
European Green Vehicles Initiative	750
5G networks for the Future Internet	700
High Performance Computing	700
Robotics	700
Photonics	700
Total	*6,200*

5.12. European Technology Platforms (ETPs)

Industry-led stakeholder fora that define medium to long-term research and innovation agendas and roadmaps for action at EU and national level, ultimately enhancing European competitiveness. They are organisations independent from the European Commission, although the Commission participates in their events as an observer. Some Member States have established national technology platforms to mirror ETPs: some to build capability and enable their research communities to influence and participate in European activities, others to align their activities with the shared strategic vision.

There are ETPs placed in the areas of bio-based economy, energy, environment, ICT, production and processes and transport. For the updated list of current ETPs please refer to the official website.

5.13. High Level Forum for a Better Functioning Food Supply Chain

The forum identifies challenges affecting the competitiveness of the agro-food industry and advises the Commission on how to tackle them. Recommendations are addressed to both policy makers and private stakeholders. It comprises all EU Member State national authorities responsible for the food sector at ministerial level and representatives of the private sector (namely organisations actively involved in the agro-food industry and in the trade and distribution of agro-food products in the Union, EU umbrella associations and federations in the aforementioned sectors, and non-governmental organisations with expertise in matters relating to the food supply chain). One of its past activities was to discuss ways to improve the sustainability of the food system.

6. Appendix 2. List of Contributors

6.1. Leadership Team of the ETP Food for Life

Industrial Members

- Gert W. Meijer, Deputy Head Corporate Regulatory and Scientific Affairs for Nestlé (**CHAIR)**
- Didier Bonnet, Global Food Research Leader for Cargill
- Ellen de Brabander, Senior VP, R&D Nutrition global leader for PepsiCo
- Frans Egberts, Managing Director for Henri van de Bilt B.V. (SME)
- Dimitris Ladikos, R&D and Quality Assurance Director for YIOTIS (SME)
- Hanno Speis, Vice-President R&D Europe and Eurasia for Mars
- Gerhard Wagner, R&D Director DSM Biotechnology Center for DSM
- Patrick Lesueur, Open Innovation Director for Unilever

Academic and Research Institution Members

- Jochen Weiss, Professor at the University of Hohenheim **(VICE-CHAIR)**
- Remko Boom, Professor at the University of Wageningen
- Bjarke Christensen, Associate Professor at the University of Copenhagen
- Luca Cocolin, Professor at the University of Torino
- Jan Delcour, Professor at KU Leuven (member of the SAB of the JPI HDHL)
- Tim Hogg, Associate Professor at the Catholic University of Portugal
- Liisa Lähteenmäki, Professor at Aarhus University

6.2. Scientific Workgroup Members

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