Attachment 6.5 to Deliverable 2.1

Report on baseline and description of identified trends, drivers and barriers of EU food system and R&I - Description of Trends

Work package number and title:	WP 2 Mapping of trends in food systems and related R&I policy frameworks
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Relevant Task:	T 2.1.1
Dissemination Level:	Public
Due Date (month):	M10
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

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1. MEGATRENDS

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CLIMATE CHANGE

MEGATREND/CHALLENGE

Between 1880 and 2012, the average temperature of the global land and ocean surface increased by 0.85°C, the temperature in the arctic even by 2°C. In the northern hemisphere, the last 30 years are the warmest in the last 1400 years. Because of increasing CO_2 emissions and their strong, almost linear, relationship with the projected temperature change, further warming over the next few decades seems inevitable.

SHORT DESCRIPTION

Anthropogenic greenhouse gas (GHG) is considered a major cause for the overall warming. CO_2 emissions are responsible for around 75% of global GHG emissions. Major emitters of GHG are the combustion of fossil fuel (CO_2) and agriculture (methane and nitrous oxide). Climate change will have profound impacts on water and food security.

The overall temperature of the oceans will rise and the water will acidify. In addition, the arctic region will continue to warm and the melting polar caps will also account for the rise of the global mean sea level. Extreme weather events such as heat waves are expected to occur more often and last longer, while extreme precipitation events will become more intense and occur more often in certain regions. Extreme rainfalls will influence water availability and supply, food security, and agricultural incomes. It is expected that there will be a detrimental impact on the yield of the major crops such as wheat, rice and maize. Renewable surface water and groundwater resources are likely to become scarce in the dry subtropical regions.

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DEVELOPMENT-DYNAMICS AND DRIVERS

The dominant cause of the observed increasing temperature since the mid-20th century is attributed to anthropogenic greenhouse gas (GHG) emissions (e.g. carbon dioxide (CO2), methane and nitrous oxide). The global increases in GHG concentration are due primarily to fossil fuel use, land use change, and agriculture. CO2 emissions account for around 75% of global GHG emissions; most of them are emitted during energy production processes (approx. 60% of CO2 emissions come from fossil fuel use). Agriculture is a major emitter of methane and nitrous oxide. It is projected that global temperature change during the 21st century will be almost linear to cumulative CO2 emissions. [1]

Greenhous gas emissions are further intensified by global tree cover loss (e.g. deforestation, forest fire and natural loss). Forests and vegetation account for 30% absorption of CO2 emissions [2].

CONSEQUENCES ON FNS / SOCIETY

In future there will be increased frequencies of extreme climatic events (more heat waves, more intense and frequent extreme precipitation events). The oceans will continue to warm and acidify, and thereby influence the marine ecosystems and lead to changes in the distribution of marine fisheries. The global mean sea level will continue to rise and flood coastal lands, leading to salination and/or contamination of water and agricultural lands. The Arctic region will continue to warm more rapidly than the global mean, leading to further glacier melt and permafrost thawing. [1]

Climate change is expected to have severe consequences for food and water security, and create new risks and challenges on the global level. It will affect the availability of water with good quality, the timing and length of growing seasons, the distribution of agro-ecological zones and it will increase ecosystem stresses (erosion by water and wind, acidification, salinization, biological degradation). However, it will affect not only food production, but also food processing, distribution and consumption. Therefore, it will have major impacts on agricultural incomes, and will lead to shifts in the production areas of food and non-food crops around the world. While low-latitude regions are likely to suffer most from climate change effects, higher-latitude regions are most likely to benefit from longer and warmer growing seasons. Because of higher temperatures, limits of agriculture in the northern hemisphere will be extended and key agricultural systems will need to cope with new stresses and risks. In seasonally dry and tropical regions, even slight warming is expected to reduce yield and consequently may also cause increases of food prices. Climate-related animal and plant pests and diseases and invasive aquatic species will reduce overall food availability. At the same time, we can also expect beneficial effects on crop production through CO_2 "fertilization". However, increasing frequency of crop loss due to climatic extreme events may overcome positive effects of temperature increases. There will be a negative impact on yields and quality of the major crops such as wheat, rice and maize for most countries, however, the poorest countries around the world will be affected the most. The driest subtropical regions will be confronted with increased competition for water. Therefore, poor or marginalized rural populations that mainly depend on agriculture, forestry, and fishery sectors are the most vulnerable and strongly affected by climate change. Consequently, global shifts in food production will even increase the already existing imbalances between developed and developing countries. [3]

CHALLENGES – NEEDS FOR R&I STRATEGIES

Climate change and food security are twin challenges which need to be addressed together. Reducing and managing their risks will require a mixed strategy of mitigation and adaptation. The extent of mitigation efforts will determine levels of future GHG emissions. [1] Climate impact studies should also address food security aspects other than crop yields. Given the serious threats, action-oriented research is a priority. Furthermore, stakeholder-driven portfolios of options should be a focus for research. [4]

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MALNUTRITION

CHALLENGE

Combating malnutrition in all its forms is one of today's greatest global health challenges.

Currently, about 45% of deaths among children under 5 years of age are linked to undernutrition. These mostly occur in low- and middle-income countries. [1]

More than 500 million people are expected to suffer from hunger and malnutrition in the less developed countries in 2030.

SHORT DESCRIPTION

There are three major forms of malnutrition: undernourishment (due to lack of sufficient food), micronutrient deficiencies (due to inadequate intake of vitamins and minerals), and overweight / obesity (due to the low nutritional value of food and high-caloric food). Malnutrition cause high social and economic costs for individuals, families, communities and governments.

During the last decade, access to food has worsened particularly in parts of sub-Saharan Africa, South-Eastern Asia and Western Asia. Deteriorations concerning the food situation have occurred particularly in areas with conflicts and conflicts combined with droughts or floods.

Because of the expected global population growth, climate change and loss of agricultural land due to soil degradation, global food security will be one of the major challenges of the future.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Although the world is increasing its food production each year, and present global food stocks would be sufficient to provide everyone in the world with the food required for a healthy life, the hunger population is continuously increasing because of an inequality in the distribution of food supplies. In affluent regions, food surpluses are often used to feed livestock or to produce energy. Food production in ecologically disadvantaged regions is frequently obstructed by disaster (floods, drought, wars, etc.). As a result, micronutrient deficiencies, chronic undernutrition and poor-quality diets are endemic in many, predominantly poor, countries.

Malnutrition takes many forms. Even though people might have access to enough calories, this does not guarantee an adequate intake of essential micronutrients such as vitamins, minerals and trace elements (e.g. iron, vitamin A) and leads to micronutrient malnutrition (also known as hidden hunger) with its serious public health consequences. This condition affects more than two billion people globally, and can contribute to stunted growth, poor cognitive development, and complications during pregnancy and childbirth. In addition to the direct effects of malnutrition on health, malnutrition also interacts with many infectious diseases (e.g. infection of malaria, measles, persistent diarrhoea and pneumonia), increasing the severity of symptoms and raising mortality rates. [4]

In addition to climate change, rising bioenergy demands and soaring food prices, the following factors contribute also to malnutrition: demographic forces and urbanisation, structural shifts in food and agricultural systems, transboundary movement of disease; and environmental and energy pressures.

CONSEQUENCES ON FNS / SOCIETY

Food insecurity and malnutrition represent serious impediments to sustainable development, poverty reduction, equity and achievement of the Sustainable Development Goals (SDGs). They have four dimensions: food availability, stability of supply, access to adequate quantities and varieties of safe, good-quality food and utilization by the body. Stability of food supply depends on food production, incomes, and markets and can be adversely affected by extreme weather events, price fluctuations, human-induced disasters and political and economic factors.

CHALLENGES – NEEDS FOR R&I STRATEGIES

An understanding of the socio-economic causes and consequences of malnutrition is essential for formulating appropriate policies to improve nutrition. More research into the long-term effects of food insecurity on nutritional outcomes is also needed to strengthen the evidence base. It is vital that all strategies comply with the local conditions. For example, low food production caused by insufficient agricultural productivity is a primary reason for hunger in tropical Africa and remote parts of Asia and Latin America. In contrast, income poverty may be the primary reason for hunger in South and East Asia, Latin America, Central Asia and the Middle East.

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RISE OF NON-COMMUNICABLE DISEASES

CHALLENGE

Currently, 1.9 billion adults and 41 million children are overweight or obese. [1]

Overweight and obesity rates are rising quickly worldwide and lead to increases in non-communicable diseases (e.g. cardiovascular diseases, diabetes and cancer). Unhealthy and nutritionally poor diets are major risk factors.

SHORT DESCRIPTION

Dietary factors are the most important factors that undermine health and well-being. Changing consumption patterns in developed and emerging countries and "western" influences on the diet has led to a continuous rise in non-communicable diseases, such as obesity and associated diseases.

Non-communicable diseases resulting from unhealthy diets cause high social and economic costs for individuals, families, communities and governments.

By 2030, 75% of the forecast 67 million deaths per year will be related to non-communicable diseases. The annual number of deaths due to cancer will rise by 60%, due to cardiovascular diseases by around 40%.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Malnutrition is associated with the increase of chronic medical conditions. Excessive consumption of energy, saturated fats, trans fats, sugar and salt, as well as low consumption of vegetables, fruits and whole grains are risk factors for obesity and related future diseases. The prevalence of obesity has increased alarmingly across the world.

Today, the world is producing more food than ever before. In the food industry, higher profit rates can be achieved easier through processed food than through the raw ingredients. Therefore, processed food often uses additives in food production such as water, salt, fat and sugar, as they are most cost effective.

In many countries, people with low socio-economic status have a higher risk of dying from non-communicable diseases (NCDs) than more advantaged groups and communities. Consequently, NCDs are responsible for most morbidities and mortalities in low- and middle-income countries. A major driver for this is an ongoing nutrition transition process. [3] It is a shift in food consumption patterns from diets low in calories and nutrients to diets high in calories but still inadequate in their balance of nutrients. Excessive energy intake relative to energy expenditure (combined with less physical activity), together with a lack of inadequate consumption of nutrients, is often associated with an increase in obesity and chronic diseases such as diabetes, hypertension, stroke, hyperlipidaemia, cardiovascular disease, and cancer.

CONSEQUENCES ON FNS / SOCIETY

Of the six WHO regions, the European Region is most severely affected by NCDs. The four major NCDs (cardiovascular disease, diabetes, cancer and respiratory diseases) account for 77% of the burden of disease and over 80% of premature deaths. [4] In addition to unhealthy diets and physical inactivity, tobacco use and the harmful use of alcohol also increase the risk of dying from an NCD.

In countries with inadequate health insurance coverage, the enormous costs of care associated with NCDs, often caused by lengthy and expensive treatment and loss of breadwinners, can push families further into poverty.

Many low- and middle-income countries are now facing a "double burden" of disease: On the one hand they have to cope with the problems of infectious diseases and undernutrition (esp. nutrient deficiencies), and on the other hand they have to deal with a rapid upsurge in NCD risk factors such as cardiovascular diseases and obesity.

It is anticipated that in 2030, the following three diseases will be the most common causes of death: 1. Coronary heart diseases; 2. Cerebrovascular diseases; 3. Chronic obstructive pulmonary disease (COPD)

CHALLENGES – NEEDS FOR R&I STRATEGIES

Country-specific information on extent and patterns of NCDs as well as their social impact need to be identified. The application of primary and secondary care cost-effective interventions needs to be identified and explored, and the gaps in accessibility and affordability of essential medicines and technologies required for treatment of NCDs should be assessed. Furthermore, multidisciplinary research approaches will be necessary to elucidate the influence of sociodemographic and economic factors on NCD prevention and control, to enhance availability and accessibility of cost-effective interventions to lower socioeconomic strata, and to increase the uptake of evidence-based research for policy development by policymakers. [5]

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URBANISATION

MEGATREND/CHALLENGE

In 2008, 50% of the world's population lived in cities. In 2030, about 60% of the global population will live in cities. In less developed countries, about 3.9 billion people will then populate urban areas. Although cities cover only 2% of the Earth's surface, they produce 80% of global economic output, 70% of global greenhouse gas emissions, and consume 75% of the global energy.

SHORT DESCRIPTION

Urbanisation is mostly due to the migration of people form rural areas to cities. This is often a consequence of the declining economic significance of agriculture and forestry, rural poverty or lack of infrastructure (schools, jobs). Even though urbanisation is a global phenomenon, as all countries around the world are becoming more urbanised, urban populations are growing most rapidly in Africa and Asia. In developing countries urbanisation could bring about several advantages to the population such as better access to electricity, water and sanitation. Urban dwellers usually have also good access to sufficient and fresh food; however, the urban poor often experience low-quality food and suffer more often from lifestyle-related obesity and chronic disease than rural populations.

When cities develop faster than intended by their planners, the development of the infrastructure (e.g. public transport) often lacks behind the actual needs. Cities are prone to environmental problems such as air pollution and the associated health problems, noise, land consumption, declining water quality and as well as slum formation.

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DEVELOPMENT-DYNAMICS AND DRIVERS

It is projected that in 2050 nearly two thirds of the world's population will be living in a town or city, or even in a mega-city. The biggest population growth is expected to occur in urban areas in the less developed countries in Africa and Asia. Living in cities is - especially in developing countries - usually associated with advantages such as access to electricity, water and sanitation. In addition to better living conditions, cities offer more hope of jobs. The main drivers of urbanisation are: national and regional economic development; demographic growth; and an increase of personal income.

Migration from the countryside to cities is commonly considered the major reason for urbanisation. However, this assumption is flawed. Urban population growth usually comprises three factors: endogenous population growth (or urban natural increase), in-migration from rural areas, and the transformation of previously rural settlements into urban ones (i.e. reclassification). There is growing evidence that migration from rural areas plays a far less significant role in accelerating urbanisation. However, there are exemptions such as China, where rural to urban migration has recently predominated because of economic reform policies with a pro-urban focus. [2]

In some parts of the world, the primary reason for migration to cities can be found in disasters such as drought, famine, ethnic conflicts, civil strife, and war. However, many of these migrants may end up in low-income, poorly-serviced settlements or slums. [3]

CONSEQUENCES ON FNS / SOCIETY

Depopulation of rural areas (e.g. because of a lack of job opportunities) can be a threat to the existence of villages, reduce tax income for municipalities, and rise the per-head costs for public services. Rural areas will be facing stagnant economies, inequitable land distribution and degraded environments. Yet, urbanization also presents many human development challenges and an expansion of slums. New urban residents are likely to be confronted with unemployment. [3] In many cities worldwide, economic growth in the cities has not resulted in well-being and prosperity for all, but in an intensification of the gap between the rich and the poor. Especially sub-Saharan Africa faces high levels of urban poverty. It is expected that by 2035 cities will become the main places for poverty.

The development of urban areas is highly dependent on the creation of food surplus in the rural areas. Nowadays, while many cities of developed countries depend on highly unsustainable food sources, cities of developing countries still tend to source food that is locally grown. Urban agriculture is a key factor for food security, especially for low-income communities.

A major drawback entangled to urbanisation is a possible lack of urban water supply and sanitation, over-exploitation and pollution of water resources. Inadequate infrastructure (e.g. lack of wastewater treatment and drainage facilities) can cause pollution of water supplies. [4] In addition, unreliable power systems, congested roads and poor public transport, inefficient ports and inadequate schools comprise also main challenges. Urbanisation can also have a significant effect on environmental degradation, e.g. through land sealing, loss of habitats and biodiversity reduction.

CHALLENGES – NEEDS FOR R&I STRATEGIES

There is a need for rural urban planning, as the imbalance of the spatial distribution of the population as well as the wealth gap between rural and urban areas is increasing. As many people currently still live in minimum standards of comfort and sanitation, huge investments will be necessary to build new houses to accommodate the increasing numbers of citizens. Local as well as national governments will need sound strategies to respond to these challenges adequately. A national urbanisation strategy should be formulated.

Many cities located in coastal areas are prone to be affected by natural disasters such as storms and floods. Precaution measures have to be developed. In addition, it has to be researched into the state of urban poverty, food security and undernutrition in cities so that reliable data can be collected.

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DEMOGRAPHIC CHANGE

MEGATREND/CHALLENGE

The world's population is expected to rise from 7 to 8.5 billion by 2030, and to 9.7 billion by 2050. The population will grow almost entirely in less developed countries, especially in Africa. In Europe and westernized countries, population figures will rise slowly or even fall. Population groups >60 years are projected to grow the fastest. People over 80 will account for around 10% of the world's population in 2050.

SHORT DESCRIPTION

Population growth is one of the major drivers for the future food and nutrition security. Global food systems will have to provide high-quality food to the additional 2 billion people in 2050, to prevent hunger and nutrition deficiencies.

Due to the increasing number of elderly people, the share of the working age population will decline in aging countries (e.g. Japan, Central and Eastern Europe) and overall living standards might not be maintained. Migration of younger people from beyond the national boarders could counteract the trend. In addition, technological advances for the promotion of physical and cognitive capacities could allow the elderly to remain in the work progress. In contrast, some developing countries will soon see increasing numbers of young people. It is estimated that in Africa the number of young people will increase by 42% by 2030 and even double by 2055. Similarly, ongoing increase in the number of youth is also expected for the Middle East. As these young people will push into the labour market, an economic boost is likely. Life expectancy is projected to reach 83 and 75 years in more and less developed countries, respectively, by 2050.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Demographic change is a dynamic process that is driven by changes in (1) mortality, (2) fertility and (3) migration. Changes influence population size, growth rate, age structure and the distribution of the population. The higher the population growth is, the bigger is the population group of young people and the smaller is the group of elderly people. Similarly, a decline of mortality and fertility rate results in an increase of the number of elderly people.

Therefore, key drivers of demographic change are the mortality and fertility rates. A decline in the infectious and contagious diseases (due to the use of vaccinations, improved hygiene and sanitation) usually leads to a decline of the mortality rate. However, over time, more and more people will die from chronic and degenerative diseases. In low-income countries, mortality rates are still high, as mortalities are still driven by infectious diseases and neonatal complications. In Sub-Saharan African countries, a major part of the deaths occurs because of neglected tropical diseases, malaria, HIV, and tuberculosis.

Declining infant mortality rates and increasing educational attainment, life expectancy, and income usually reduce total fertility. Improving child health therefore results in lower fertility rates. Education (especially of women) is also a factor that reduces fertility. [3]

The third key driver for demographic change is migration, both within countries and across borders. Migration can have a substantial impact on age structure and population growth.

CONSEQUENCES ON FNS / SOCIETY

Because of reductions in fertility and mortality rates and an increase in the life expectancy, populations – especially westernized ones – are prone to age and the overall number of young people decreases. It is projected that by 2050 the share of people older than 65 will be around 28% in the EU. This trend has a major effect on the core working age group, and overall workforce of a developed country will shrink in the near future, unless countermeasures occur (e.g. migration). Although now aging mainly affects developed countries, it is expected that aging societies will also become a relevant factor for developing countries in the second half of the 21st century.

As the overall world population grows (especially in Asia and Africa), the demand for food and water also increases dramatically. Food production is a major consumer of water. In addition, an increase of consumption will also result in an increased water use for manufacturing and production sectors. The ongoing trend of urbanisation results, however, in a decrease in the number of farmers.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Demographic change is one of the major social policy challenges of the future. In Europe, the “baby boomer” generation is now about to retire. Adjustments that come with an ageing society are now to be tackled. Society, the state, politicians, academics, and every individual will face huge challenges, as the population will age more rapidly in the near future and shrink in size at the same time. The state and society will have to develop suitable strategies to manage the ongoing demographic changes, especially, in the education system, the labour market, the healthcare systems, infrastructure areas, the administrative and finance systems, and in security matters.

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MIGRATION

MEGATREND/CHALLENGE

Over the last decade the number of migrants has increased from 150 million to 214 million and is likely to triple by 2050 to 405 million. There is inward migration as well as outward migration.

Inflow of young migrant workers will be a crucial factor to counteract ageing societies in most westernized countries.

SHORT DESCRIPTION

Migration occurs both within national boundaries (e.g. when moving to cities) and across international boundaries. The reasons for migration are manifold and include demographic differences, negative impacts of climate change (drought or other natural catastrophes), poverty, civil unrest, and war. In addition, people also migrate because of family, professional or economic reasons. Because of an increase in migration movements, global competition for jobs will also increase. This is true for both, highly skilled and semi-skilled workers (or even unskilled workers).

The most common trends of migration patterns comprise: globalization (migrants come from a wide variety of countries); increase in the number of people involved; a growing number of migrant categories; an increasing number of migrating women; migration due to political reasons; and transition of countries that have traditionally been countries of emigrating to countries of immigration.

A substantial proportion of migrants comes from rural areas. Male out-migration results in a feminization of the agriculture in many low-income countries.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Migration occurs either from a given place away or to a given place. Drivers for migration include economic inequalities (e.g. differences in wages, employment prospects, or access to specific services) and other inequalities such as differences regarding security from physical harm, violation of human rights, and limitations on religious or personal freedoms. While countries with higher incomes tend to be the preferred destinations for migrants, the migrants most often come from developing countries. [2] It is assumed that about 3% of the world's population will be migrants in 2030. [4] A growing number of migrants will be moving within Asia and Africa, as the economies of both continents are expected to develop economically.

In addition, warfare and environmental disasters have also become important drivers for migration. Environmental-related migration occurs most frequently in Sub-Saharan Africa, as well as in Asia and India. Migration is usually not only driven by extreme weather events (e.g. storms, floods) or gradual ecological change (e.g. due to soil erosion or a rise of the sea-level), but because of a complex set of interrelated environments, social-economic, cultural, political and demographic factors.

However, the largest migratory flow is expected to occur within country, i.e. from rural areas to cities. This will often be driven by high fertility rates combined with limited job prospects, as cities usually offer better jobs and educational opportunities. By 2050, most of the urban growth will be seen in the developing countries. [4]

CONSEQUENCES ON FNS / SOCIETY

Modern farmers are profiting less and less from their labour. Consequently, over the last decades, a continuous decrease in farm labour and in the number of farm holdings has been ongoing, also in Europe. [4] Farmers that cannot generate sufficient income must find other ways of living, which often leads to out-migration.

In the future, the total fertility rates will continue to be low in the wealthy countries around the world, including key Asian countries such as Japan and Korea. International migrant workers will be important for mitigating ageing populations in most industrialised countries and contribute to overcome anticipated labour and skills shortages in the receiving countries. Consequently, ethnic communities are expected to grow, however, they might not be integrated fully by the host population and economically disadvantaged, which may lead to tensions.

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CHALLENGES – NEEDS FOR R&I STRATEGIES

Global migration flows are growing in complexity, direction and magnitude. An estimation of the number of migrants is usually difficult, as it depends strongly on the categories that are either included or excluded in the calculations. Among the migrants that are usually included in the calculations are the highly desirable and needed people (e.g. students, legal temporary workers); among the migrants that are usually not included are people that are either residing illegally in a country or that are less desirable (unauthorised migrants).

For the future it will be important for the receiving countries to develop strategies for attracting needed migrants to meet labour market needs and to study how migrants are choosing their destination.

Because of the speed of immigration growth and cultural and/or religious differences, anxieties about social and cultural change have been fuelled among the residents in the receiving societies. Lack of satisfying management of immigrant integration as well as structural unemployment in parts of the wealthy countries add to this anxiety. A better management of migrant integration could contribute to more effectively reap the benefits of migrants in the receiving countries. In addition, it will be necessary to know the long-term concerns of the countries of origin and to be more mindful of them.

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SCARCITY OF NATURAL RESOURCES

MEGATREND/CHALLENGE

The availability, accessibility and usability of natural resources are prerequisites for prospering economies including the agricultural sector. High-quality land and the availability of water and nutrients are the basis for food and renewable energy production. Yet, the quality of land suitable and available for agriculture is increasingly threatened by degradation due to over-exploitation, pollution, the impact of climate change, competition for land and shortage of available water.

SHORT DESCRIPTION

Competition for natural resources is likely to limit food production in the long run. There is growing consensus that scarce resources, such as water and carbon storage, and rare elements (e.g. rare earths, phosphorus) should provoke a more efficient way to use the resources, e.g. also by means of technical improvements.

Water demand is projected to increase by 55% between 2000 and 2050. In 2030, almost half of the world's population will live in regions where water supply is limited. Although agriculture will remain the largest consumer of water, there will also be an increasing demand from manufacturing, electricity production and domestic use. In addition, groundwater will be used up faster than it can be replaced. Intensive farming operations can also be a major source of water, soil, and air pollution.

Phosphorus

The growing demand for natural resources has already caused tremendous damage to ecosystems and is likely to lead to irreversible losses for humankind.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

The growing world population and global economy is likely to be accompanied by an increase in the demand for water, food and energy as well as other rare commodities (e.g. critical raw materials such as rare elements). Water demand has already outpaced population growth during the last century. As there are no viable policies that aim to regulate water management, it is expected that water demand will increase by 55% between 2000 and 2050. Although agriculture will remain the largest consumer of water in the future, manufacturing, electricity generation and domestic use will also increasingly draw on water reserves. [1] By 2050, groundwater depletion may become a great threat to agriculture and urban water supplies. In addition, the water is becoming increasingly polluted, also through nutrient flows from agriculture and poor wastewater treatment.

Technological advances in fishing methods such as sonar technology for deep water fishing and large trawlers for fishing on the ocean floor has led to overfishing and has resulted in a decline in total wild fish since the 1990s. Carnivorous farmed fish such a tuna has also contributed to overfishing, as for one kg of farmed fish 20 kg of wild fish are needed. In addition, farming of herbivorous fish such as salmons produces vast amounts of nitrogen sewage. [2]

Population growth and urbanization will entail an increasing demand for energy. In 2030, most energy will still come from fossil fuels, even though it also risks accelerating climate change.

It is projected that the demand for critical raw materials will also continue in the future. Most critical raw materials are produced outside of Europe. Currently, China is the major supplier of rare earth elements and phosphorus. Conflict over these rare materials could arise between developed and developing countries.

CONSEQUENCES ON FNS / SOCIETY

Natural resources are essential input factors for economic growth as well as for the life of human beings, animals and plants. Most of them are not renewable. Resource scarcity is expected to continue. Without reducing consumption and dependency, competition and conflict over scarce resources will become a likely reality. For example, phosphorus, an essential nutrient for life, with large mine in Marocco, Russia, China and the US, is heavily used as a fertilizer worldwide. Shortage of the element will affect prices of agricultural produce dramatically and thereby world nutrition.

Due to the ongoing exploitation of the natural environment and climate change it is expected that there will be continued soil degradation and erosion in the coming decades. Soil degradation will affect the amount of land available for productive agriculture. [1]. Modern food production is responsible for extracting tons of nitrogen and phosphorus and other vital nutrients from soil. Through the supply of food and feed for animal feedlots and urban centres, soil nutrients are accumulated there and rather burned or discarded as waste instead of recycled in closed circle economy systems. Another reason for nutrient loss is due to erosion, after organic residues have been removed from the soil surface.

Groundwater/freshwater is the most used raw material in the world. Agriculture is the largest user of groundwater (approx. 60% of the global usage). Agriculture uses water predominantly for irrigation and in the production of animal feed, fertilizers and pesticides. This is intensified by a current trend towards diets that include more meat and dairy products. In addition, irrigation practices on naturally dry land can cause salinization. It occurs when water evaporates from soils due to high temperature and draws salts from the soil to the surface.

Excessive use of natural resources can lead to long-term water and food insecurity as well as geopolitical insecurity. Depletion of natural resources will increase the likelihood of violent internal or international conflicts, especially in developing countries. Disputes over water and fishing rights have already become more common in recent years. The pressure for action will grow.

CHALLENGES – NEEDS FOR R&I STRATEGIES

To reduce the exploitation of water it is necessary to limit wastage. In agriculture, more efficient irrigation systems need to be developed. To handle scarcity of rare raw materials, companies have to invest in innovative technologies for remanufacturing, recycling and material reduction as well as in new technologies that are less dependent on rare elements.

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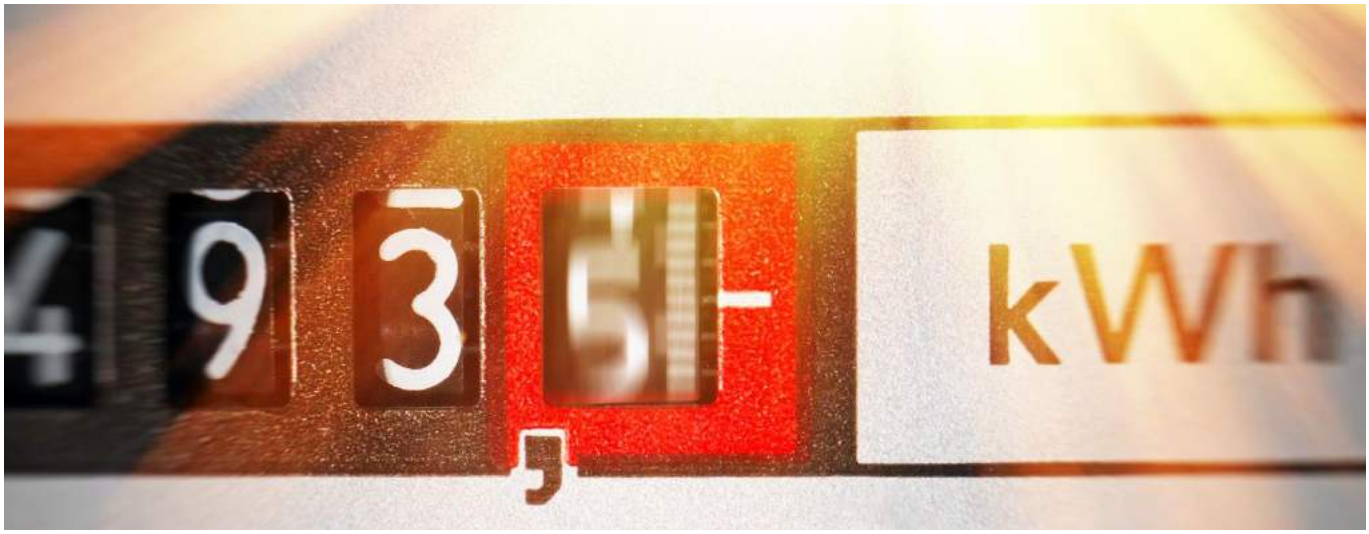
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

RISE IN ENERGY CONSUMPTION

TREND



The global primary energy demand is expected to increase by 37% between 2012 and 2040. In 2040, the largest consumers will be industry (rise in energy demand by 40%), transportation and commercial and residential buildings.

SHORT DESCRIPTION

It is expected that global energy consumption will rise sharply in the next two decades due to increasing population numbers and the global economic growth. While the biggest increase of energy consumption is projected to occur in China and India, energy consumption in OECD countries will not change substantially. Consequently, it is also expected that the demand for fossil fuel will continue to grow until 2040, however, the share of fossil fuel in the overall energy mix is likely to decline.

For example, trends in the transportation sector indicate an increasing demand for cars because of the likewise increasing number of affluent middle-class people. Because of efforts to improve fuel efficiency, the energy demand for cars is not likely to increase proportionally to the demand in cars. The share of hybrid vehicles purchased is expected to reach 50% in 2040. A similar trend is reflected in the patterns of energy consumption of buildings. Households will rely even more on electricity than fossil fuels. The expected continuous rise of the oil price will be the main reason for globally rising energy prices. However, rising prices for electricity and gas can also be expected for the coming years.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

It is projected that energy consumption will rise sharply until 2040 due to population and economic growth, particularly in Asia. Then, industry will remain the largest consumer of energy. However, the growth in energy demand will depend on the industry subsector. The chemical sector is expected to have the highest increase in energy use due to the increasing demand for plastics and other chemicals. The ongoing trend to shift away from coal and oil in the OECD countries is expected to continue until 2040.

Transportation is projected to be the second largest consumer of energy in 2040. Because of the growing middle class, the overall number of cars is expected to increase as well. Since the fuel efficiency will increase, the overall energy consumption of cars will rise only moderately. The amount of hybrid vehicles is projected to reach 50% of new-car sales in 2040. Commercial transport – including airplanes, shipping, trains and trucks – will be responsible for most of the growth in energy demand from transportation. [1]

Commercial and residential buildings will be another large consumer of energy in 2040. They are expected to rely mainly on electricity for the use of household devices rather than on primary fuels. [1]

Overall, future scenarios indicate that the demand for fossil fuels will still grow by 2040, however, the share of fossil fuels within the overall energy mix is expected to decline. More and more renewables will be used for energy production (e.g. wind power, hydropower, solar technologies and biofuel). However, unless there will not be more stringent climate mitigation policies, fossil fuels will remain the dominant part in the fuel mix. The Middle East and the Russia/Caspian region are likely to remain the largest oil exporters over the next decades, while Asia Pacific and Europe will remain the largest importers. [1]

CONSEQUENCES ON FNS / SOCIETY

The future price of oil is uncertain, and its variability influences the health of any economy. Falling oil prices can contribute to economic growth, as they directly influence the costs of transportation of goods, and the production of materials based on oil products. Lower transport costs change the dynamics of trade, and make the transport over long distance more attractive.

In contrast, high oil prices – often caused by political instabilities in the Middle East – can stimulate the demand for biofuel or other renewables as an alternative source of energy. Cultivated crops such as maize and sugarcane, are increasingly used as alternatives to crude oil, e.g. to produce ethanol. Although crop diversion promotes independence from external energy sources and can improve fuel efficiency, it exhausts limited soil, water and land resources for non-food purposes and thereby threatens both current and future food supply.

In addition, increased energy costs have another direct impact on food production and rural livelihoods, as they increase costs for operating farm machinery, fertilizers and transportation of both inputs and farm products. [2]

CHALLENGES – NEEDS FOR R&I STRATEGIES

The projected ongoing increase of demand for energy stirs research into two directions: on the one hand there is a need for alternatives and effective energy sources for crude oil, and on the other hand there is a need for innovative strategies to modify energy consumption. The overall energy consumption could be reduced by relying on research-based strategies, target-oriented investments, and modern technologies. Also, an effective way to reduce the energy consumption is efficient management of energy demand.

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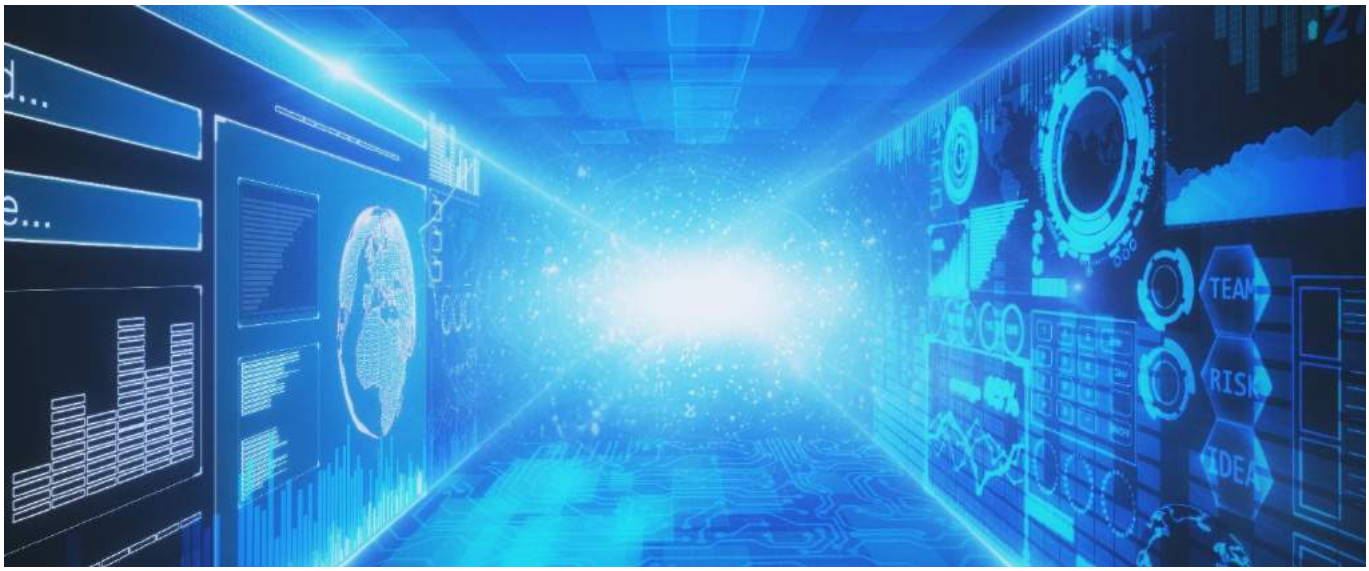
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

INDUSTRY 4.0 – DIGITIZATION IN FOOD PRODUCTION

MEGATREND



The next production revolution will occur because of a confluence of technologies. These range from a variety of digital technologies (e.g. 3D printing, the Internet of Things - IoT, advanced robotics) and new materials (e.g. bio- or nano-based) to new processes (e.g. data-driven production, artificial intelligence, synthetic biology).

SHORT DESCRIPTION

The term “Industry 4.0”, or the fourth industrial revolution, refers to the use in industrial production of recent and often interconnected, digital technologies that enable new and more efficient processes, which in some cases yield new goods and services. The associated technologies are many, from developments in machine learning and data science, which permit increasingly autonomous and intelligent systems, to low-cost sensors which underpin the IoT, to new control devices that make second-generation industrial robotics possible. Digitization offers enormous potential not only for smart farming but also for all steps in the food supply chain from food production, packaging, food distribution to nutrition. For example, digitization allows for better control and inspection of food quality; delivery is made possible even for small batch sizes, as virtual connection of the whole supply chain is made possible through interconnected digitalization. Machine learning and artificial intelligence is to ‘steer’ the food processing. Blockchain technologies, intelligent (smart) packaging and direct communication to the consumer via the retail support the distribution chain of food. Consumers have ‘tools’ at hand to check the nutritional value or allergic risk of products as well as to check their own health parameters to decide on their daily diets.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

Constant pressure on prices has forced the food industry to continuously follow innovative paths. As technology plays a significant role in food industry, this sector expects also to benefit from the new paradigm of Industry 4.0. Industry 4.0 is driven by advances in connected manufacturing and comprised of growing trends in automation, the Internet of Things, big data, and cloud computing technologies. It aims at supporting industry in developing its role in a much more efficient and collaborative way. With regard to the food sector, the adoption of Industry 4.0 offers technological development and dynamization of the economy, production flexibility by making configuration changes that do not affect production time, personalization that allows satisfying client requests even under low production volumes, optimization of the decision making process by real time handling of information, an increase in productivity and efficiency of resources throughout an exhaustive tracking along the entire productive process, increased connectivity across entire businesses and the creation of new business opportunities. [1]

The Internet of Things has been crucial for the development of Industry 4.0 as it allows for interoperability of machines, sensors and other devices. The sensors in networked physical connected devices collect data in real time. Big data, advanced analytics and cloud computing help to store or transform large sets of data into meaningful information and support business operations from remote working environments.

CONSEQUENCES ON FNS / SOCIETY

In the food industry, Industry 4.0 is changing the way raw materials are procured, food is manufactured, products are packaged and items are sold. The entire journey from farm to table is being analysed and controlled. The digital transformation of the manufacturing industry enables food and beverages manufacture to optimise the manufacturing process towards a more sustainable and efficient production and to better respond to consumer demands, covering the demand of global markets. [1]

As the machines involved in the production process are interconnected, they can monitor the manufacturing process in real time and make decentralized decisions based on data exchanged between the networked machines. Each product item will become traceable. Consequently, it is possible to identify and trace a food product from cultivation to the production chain in the food processing environments, which helps to better predict and control the food quality. Furthermore, blockchain technology could support process transparency from plant to the customer.

The flexibility of the system also allows for dealing with smaller batch sizes, quick adaptation to changing product specifications (e.g. nutritional value, allergic risk) and thereby to adapt to the demands of each individual customer. Every piece of the data, from raw material specifications to product information, can be accessed on virtual platforms by every stakeholder.

On the other hand, the consumers can apply tools to check the nutritional value or allergic risk of the produce and decide on the daily diet after checking his / her own health parameters.

The combination of interconnected autonomous machines and big data analytics could also help to identify maintenance issues and quickly react to them. Energy consumption can also be controlled and monitored, and optimized to most economical levels. In addition, the application of the Internet of Things can help to improve the logistics.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Today, Industry 4.0 in the food industry is still at its very beginning. It is likely that there are still many operational and strategic issues that will create obstacles for organizations. Because data management and storage happens largely in the in cloud, data security will be of foremost importance, as proprietary operational knowledge needs to be made secure. Whether Industry 4.0 will become a viable path, will depend on the readiness of organizations to adapt to the coming changes.

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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

BIG DATA ANALYSIS

MEGATREND

Big data analysis is expected to revolutionize the agricultural industry. Accurate crop predictions are possible by using sophisticated computer algorithms that analyse decades of weather and crop data. Big data are used to design chemically engineered seeds. Combinations of the internet, data analytics, improved sensor techniques and the use of drones for data gathering allow for agricultural automation that goes far beyond precision farming.

SHORT DESCRIPTION

Big data are massive volumes of data that cover a wide variety and that can be captured, analysed and used for decision-making. Although the exploitation of big data for (smart) farming is still in an early development stage, it is likely to change the scope and organisation of farming and the farming methods applied fundamentally.

It is expected that big data applications will cover issues such as food security and safety, sustainability and efficiency improvement. They will not be restricted to primary production in farming but cover the entire food supply chain down to delivery (smart logistics, physical internet) and communication with the consumer. The wirelessly connection of all kinds of objects and devices in farming environments as well as the supply chain will produce many new data that can be accessed in real time and analysed to create value of the data.

Consequently, big data can be used to provide predictive insights in farming operations, drive real-time operational decisions, and redesign business processes for business models. They can even help to elucidate the impact of agriculture on the environment. Challenges of big data analytics include issues concerning data ownership and potential shifts in power relations among different stakeholders in current food supply chain networks in the long run.

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DEVELOPMENT-DYNAMICS AND DRIVERS

The development of big data and smart farming is driven by a variety of pull and push factors.

For farming to be profitable in the long run, farmers need to find ways to improve profitability and efficiency through lower cost price or better market price for their product. This can be promoted by improved decision making and management control. In the past, farmers relied on general data from external advisory services or personal experience for decision making. The application and analysis of big data promises that information and knowledge can be generated on farm within the local-specific context. This should also help to deal with highly volatile factors such as local-specific weather and climate data. Another pull factor for big data applications can be the relief of paperwork arising from relevant regulations in the agri-food sector. Global food security is also considered a main driver for scientific and technological advances. In addition, consumers are increasingly concerned about food safety and nutritional aspects of food related. [2]

Among the push factors are the general technological developments such as Internet of Things in which smart machines are interconnected and operate wirelessly as well as precision agriculture. Another driver for big data are sophisticated technologies such as global navigation satellite systems, advanced remote sensing, and unmanned aerial vehicles. Wireless data transfer and advanced data analytics combined with a substantial increase of computational power are equally supportive to apply big data technologies on farm. [2]

CONSEQUENCES ON FNS / SOCIETY

Big data applications in food production go beyond primary production, as they can be applied along the entire food supply chain. Fields of application in agriculture include benchmarking, sensor deployment and analytics, predictive modelling, and using better models to manage crop failure risk and to boost feed efficiency in livestock production. Big data can be used to gain predictive insights in farming operations, support real-time operational decisions, and redesign business processes for game-changing business models. It is likely, that the use of big data technologies and analytics can cause unexpected shifts in power relations among various stakeholders in the food networks, such as tech companies, venture capitalists and small start-ups. [2]

Big data applications are likely to change the way farms are operated and managed in the future, as well as the structure of the food chain.

Big data will also exert their influence on consumers. By using customer cards and web sites with cookies, data on individual customer preferences are collected and customer profiles created. Individual social media activities also provide valuable information on consumer behaviour to companies and leave behind a digital footprint (digital shadow). These profiles do not only allow retailers to achieve the best price elasticity for certain products but even to predict short term customer behaviour. As in the EU individual pricing is legal according to freedom of contract (private autonomy), companies can now offer different prices to different customers for the same product (dynamic pricing, personalized pricing), because they know, how much the card or internet user is willing and able to pay for it. While this trend is already widespread practice with companies such as Amazon, Netflix and Coop, it may also reach food retail, especially with companies such as Amazon having entered the food market recently.

CHALLENGES – NEEDS FOR R&I STRATEGIES

As the tools, technology and machinery needed to gather the necessary data can be expensive, larger, economically stronger farms could have an advantage over smaller farms. However, once the data are collected, deciding which data sets are useful and how to use them can result in a challenging task for the farmers. Another challenge is concerned with the ownership of the data: Do the data belong to the land owners or to the providers of the data? Organizational issues concerning governance issues and suitable business models for data sharing in different supply chain models should be given research priority. In addition, there is also a need to build a sustainable digital highway for data across food systems, which requires investment into modern equipment and the creation of know-how.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

ECONOMIC GLOBALISATION

MEGATREND

Advancing economic globalisation is currently creating a multipolar global economy. The centre of this global economy will be in Asia, rather than in western countries. This overall development will also stimulate the rise of a new global middle class.

SHORT DESCRIPTION

Economic globalisation refers to the free movement of goods, capital, services, technology and information across the world, irrespective of the boundaries of national, regional, and local economies. Nowadays, economic globalisation is gradually transforming into a multipolar global economy. Driving forces behind this are political decisions to liberalise world trade on the one hand and a decrease in transportation and communication costs on the other hand.

This trend is accompanied by the rise of a new global middle class (especially in developing countries such as China and India, while the European and North American middle class basically stagnates), i.e. a new group of consumers, as members of this class can afford to spend between US$ 10 and US$ 100 per person per day. They invest their income in housing, health care, education and provision for old age. It is expected that by 2025 they will comprise about 1 billion people that are predominantly living in urban areas.

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DEVELOPMENT-DYNAMICS AND DRIVERS

During the last three decades economic globalisation has increased rapidly mainly due to technological advancement, international trade, and international investment. Economic globalisation is the economic interconnectedness of countries with the global economy through the liberalisation of trade and finance. This interdependence relates both to the cross-border exchange of factors of production (labour, capital, technologies, know-how) and the exchange of products (material goods and services, products, consumer and capital goods). The extent of globalisation is determined by political decisions that regulate economic cross-border interconnectedness, e.g. lower barriers in trade to increase trade with other countries, capital controls, and immigration regulations.

Among the key drivers of economic globalisation are [1]:

- technological drivers (e.g. innovations in transportation technology, inventions in microprocessors and telecommunications, rapid growth of the internet used for e-business and e-commerce);
- political drivers (e.g. liberalised trading rules and deregulated markets);
- market drivers (e.g. global marketing channels);
- cost drivers (e.g. sourcing efficiency); and
- competitive drivers (e.g. increased inter-firm competition).

CONSEQUENCES ON FNS / SOCIETY

Due to economic globalisation trade and foreign direct investment flows have increased respectively from 17% and 0.9% of global GDP in 1990 to 28% and 3.2% in 2016. In addition, cross-border migration of people has also increased resulting in about 10% of people living in OECD countries born abroad. Therefore, globalisation spurred productivity gains and global economic growth, the integration of emerging economies in global markets and the decrease of poverty of hundreds of millions of people. In addition, globalisation has also been instrumental to increase the link between societies and culture, and a better knowledge of other cultures. [4]

It is estimated that because of economic globalisation the number of people living in extreme poverty could be reduced by more than a billion, mostly in China and India, as both countries have pursued export-driven growth strategies. In addition, there has been a strong convergence in per-capita incomes between countries.

As a side-effect of the strong economic growth child mortality has been decreased in developing countries and material living conditions have been improved for many people in developing countries, as well, so that a new middle class has developed. The global middle class is expected to increase to up to 5 billion people by 2030, which will then be more than half of the projected world population. Rising standards of living will also increase energy consumption particularly in the residential sector in rapidly growing countries such as China, India and other Asian and African countries. In contrast, it is expected that the energy consumption will decline in households in Europe and countries such as the US and japan, due to more energy efficient technologies.

Digital distance working could become a challenge, as people can work across continents and substitute traditional and emerging professions. This could destabilise the economies of developed countries but also drain on the rural population in developing countries.

Concerning food systems and dietary behaviour, it has been shown that increasing social globalisation has a significant impact on the supplies of animal protein and sugar available for human consumption, as well as on mean BMI (body mass index). Information flows via television, internet and newspapers account for this. Yet, Trade openness has no direct impact on dietary outcomes or health. [3]

CHALLENGES – NEEDS FOR R&I STRATEGIES

The effect of social and cultural aspects of globalisation on the nutrition transition have rarely been the focus of investigations and should therefore receive greater attention in research. Research should focus on food advertising on television and the Internet. [3]

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

2. AGRICULTURAL PRODUCTION

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

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NEW AND GAME-CHANGING DIGITAL TECHNOLOGIES IN AGRICULTURE

TREND

New technologies will have a central role given the magnitude of the challenges for food security in the coming decades. The development and application of new technologies is taking place in many areas of agriculture. The areas highlighted here focus on technological and digital aspects that have a strong disruptive potential, with significant impact in the next decade. This can be enabled by the development of new platform technologies.

SHORT DESCRIPTION

Game-changing or break-through technologies can be defined as those which have the potential to be transformative and revolutionise the way we do things. They are sometimes also called 'disruptive innovations'. The development of new technologies and methods is taking place in many areas of agriculture, in the areas of crop, livestock, fuel and fibre production, of land, water and genetic resource management and of biodiversity conservation and use. Examples of integration of digital technologies are listed below, being of such nature that they have a strong disruptive potential, with significant impact in the next decade [1], [3].

- Remote sensing (use of drones and satellites, LIDAR remote sensing)
- Precision farming – automation and roboting, precision irrigation, livestock breeding
- Sensors and networks for high throughput environmental monitoring
- Hyperspectral imaging with smartphones
- Prescription farming, radical transparency, applications of big data technologies

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

Innovation is a strong feature of EU food systems. In particular, ICT developments will benefit agriculture and the food chain, although some will be disruptive and call for social innovation: could ICT help overcome a cognitive disconnect from resources agriculture depends on?

The rise of ICT in agriculture may entail a change in whole-farm management approach using information technology, satellite positioning data, remote sensing and proximal data gathering. These technologies have the goal of optimising returns on inputs whilst potentially reducing environmental impacts.

Such use of ICT will accelerate due to reductions in the costs of internet and cloud technology, which makes digital exchange of data easier. Open data (in which governments or others share their data free of charge) can be seen as an example. Together with the Internet of Things (using data from sensors, machines and other devices) and the use of data from social media this contributes to the era of big data [2].

The private sector is often the main driver of expansion in use of digital technologies in primary production, creating bottlenecks in the area of data sharing. Digital technologies in agriculture feature high on the European Union's agenda, with around €100 million available under the Horizon 2020 work programme for the period 2018-2020 to advance the development and uptake of digital technologies in agriculture and rural areas and anticipate the impacts of the digital revolution. [3]

CONSEQUENCES ON FNS / SOCIETY

Digital technologies are expected to have significant social and ecological impacts. In terms of social impacts, small farms can benefit from technology by directly connecting to consumers and retaining demand for differentiated production. On the other hand, robotization will replace (seasonal) labour, reducing the number of workers in agriculture, or increase seasonal migration. Technological advancements in agriculture are likely to require more skilled labour than before.

Digital technologies will certainly have an impact on the organisation and costs of production. Much will depend on who carries the burden of the investment in digital technologies. Moreover, whoever owns the resulting data could potentially shift the balance of power in the value chain.

CHALLENGES – NEEDS FOR R&I STRATEGIES

A 'food systems' approach may help identify the leverage points where transformation can be achieved, and collaboration between all stakeholders in the system is needed to ensure that the technology is developed in a way that it is most needed. However, to integrate new technologies into the food system the cooperation needs to go between sectors and disciplines, creating an environment that enables good communication. Not only technological develpments, but also behavioural, organisational and knowledge innovations needed for effective implementation should also be considered. Furthermore, cutting-edge technologies can bring huge benefits but these will only be realised if society is involved from the outset through two-way dialogue [4].

Technological advancements in ICT (internet of farms) requires good data facilitation strategy. In addition, the necessary infrastructure needs to be available to realize many digital technologies, which requires high investment and sunk costs. This reduces flexibility to switch to other types of technologies with different infrastructure conditions if over time food trends and demands change.

Finally, new models to simulate the global food situation and calculate the effects of interventions such as digitalization in precision farming, could have a positive impact on the environment. Those models should consider local, regional, national, transnational and global effects.

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ALTERNATIVES TO CONVENTIONAL PESTICIDES

TREND

New products and strategies are being developed in agriculture and storage that use less or no conventional pesticides. Biopesticides and Integrated Pest Management strategies (IPM) have been suggested as viable solutions to sustainably replace conventional pesticides. [1] Other approaches include tailor-made chemicals or "3D printing", i.e. assembly of small molecules to custom chemicals.

SHORT DESCRIPTION

Biopesticides are pest management solutions based on living micro-organisms, which include microbials (bacteria, algae, protozoa viruses, fungi), pheromones and semiochemicals, macrobials (insects and nematodes), and plant extracts. IPM is a systems approach that combines different crop protection practices such as monitoring of pests and their natural enemies, including biopesticides. [1]

Another approach to reduce the amount of chemicals used in agriculture and food production is the idea of tailor-made chemicals, that specifically target different problems. Small molecules have extensive untapped potential to benefit society, but access to this potential is too often restricted by limitations inherent to the highly customized approach that is currently used to synthesize this class of chemical matter. Recently, there has been substantial progress towards the iterative assembly of many different types of small molecules, including complex natural products, pharmaceuticals, biological probes and materials, using common building blocks and coupling chemistry.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

There are many pressures on the use of conventional, i.e. synthetic, pesticides, including regulatory restrictions (e.g. the EU sustainable use directive - Directive 2009/128/EC), potential ecological and environmental damage, emergence of pesticide resistance in pests and weeds (e.g. black-grass in the UK), and social pressures from consumers around potential contamination and food safety concerns. Overall, there is also greater demand for minimising or avoiding pesticide use in agricultural production, both from a health perspective (e.g. concerns regarding pesticide residues in food), and a biodiversity perspective (e.g. potential harmful impact on pollinators and consequent loss in biodiversity changes in the nutritional value of vine). The latter was also promoted by recent advances in the development of novel detection methods for conventional pesticides (e.g. by using nanomaterials in sensors).

Currently the use of chemicals in crop and pest management is part of a complex farming system involving farmers, consumers and biotech companies, each of them with their own interests. Even though the application of conventional pesticides can be considered a labour-saving technological approach (e.g. in precision farming), less harmful technologies might be more desirable. In addition, the overall amount of pesticides applied can also be reduced by using non-chemical alternatives for plant protection and pest and crop management as well as through alternative farming systems (e.g. by using a broad variety of crops, sustainable cultivation methods, promoting soil health, protection and promotion of natural enemies of pests via flower strips or set-asides, sophisticated crop rotations). In the light of increasing resistances of weeds to pesticides and the growing focus on bioeconomy, the perspectives on weeds might also change in future.

CONSEQUENCES ON FNS / SOCIETY

In the 19th and 20th century, a major goal of agriculture was to increase productivity rather than durability and sustainability. Advances in pest control via chemical pesticides have contributed greatly to an increase in the agricultural output. Yet, the interaction of agrochemicals with soil, plants, and animals is also affecting negatively overall biodiversity as well as human health. In this century, agriculture does not only aim at meeting food demands, but also at satisfying sustainability goals, even though food production and nature conservation compete for the same land. This competition for land becomes especially imminent in countries with ever-increasing population numbers that have a growing demand for agricultural products. Attaining food security and promoting food safety on a global scale, adaptation to climate and land use changes, and managing the loss of biodiversity and degradation of ecosystems are major challenges faced by society today.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Today, agriculture must deal with population growth, food security, health risks from chemical pesticides, pesticide resistance, degradation of the natural environment, and climate change. Recently, some new concepts regarding agriculture and food production have been developed, e.g. climate-smart agriculture that seeks solutions in the context of climate change, or the controversially discussed genetically engineered pesticide-resistant plants. Recent studies indicate that a better understanding of plant-microbiome interactions could also improve plant health and yield and consequently reduce the need for pesticides.

The real-life chronic exposure to mixtures of pesticides with possible synergistic effects requires in-depth research including health-related, economy-related, and society-related consequences. There is a need for new concepts in agriculture based on a reduction in the application of chemical pesticides and for holistic, co-development approaches for the development of alternative pesticides that include farmers, retailers, consumers, etc. Technological innovations are necessary for the development, implementation and adoption of sustainable crop protection systems. The transition to new and sustainable agriculture needs to be accompanied by a change in nature of these innovations such as new ways of organizing research and/or setting priorities.

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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

CHANGES IN FARM STRUCTURES

TREND

Small-scale farmers and members of their families are gradually diversifying their sources of income and employment, and many of them are ready to leave the agricultural sector entirely. This 'exit from agriculture' has taken place, for the most part, gradually over generations while land holdings are consolidated to gain economies of scale. Farmers who remain in the sector change their practices, shifting from multiple crops to monoculture, and moving away from staples toward higher value foods and cash crops.

SHORT DESCRIPTION

Farm structures are the basic units for the production of Farm structures are the basic units for the production of food and major users of land. Agricultural structures are extremely diverse ranging from small family farms to large-scale farms. International reports tend to underline the economic and social importance of small farms based on family labour, and their potential productivity gains. Large-scale farming is based on financial investment capacities. Farm structures are characterised by a combination of factors relating to the land, capital and labour used in production and by their integration into social and economic dynamics.

Over the past decades, the process of agricultural intensification has shaped changes in farm structures across Europe. The total amount of farms is declining while their average size is rising. As a consequence, many farmers exit agriculture and find employment elsewhere, while farmers under retirement are having troubles finding successors.

Meanwhile, agricultural production is becoming more specialized, moving from multiple crops to monoculture. Moreover, agriculture is becoming more capital-intensive, as farmers move away from growing staples toward higher value foods and cash crops which demand higher levels of investment [1].

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DEVELOPMENT-DYNAMICS AND DRIVERS

The most evident changes in farm structures across Europe are the declining number of farms, the farm size growth and the increased level of product specialization at these farms. Between 2005 and 2010, the number of farms in the EU declined with 3,7% each year, while the average farm size expanded with 3.8% in the same period [2].

Important drivers for these changes are agricultural policies [3], technology and productivity growth [4] as well as macroeconomic drivers [5], farm household and path dependency [6].

Recent research shows that agricultural subsidies and farmer income are an important determinant of farm structural changes in the EU. Among the older EU-15 member states, 24,8% of the variance in farm structure changes is explained by subsidies and farmer income, while this percentage is 14.1% for the newer EU-12 member states, where farm structures seems less dependent on subsidies [7].

CONSEQUENCES ON FNS / SOCIETY

The reduction of the number of farms and the intensification of agricultural production have vast social implications: less farmers are needed for the same work, causing many farmers to leave the sector and retired farmers to sell their farm instead of passing on the trade to their children. Rural communities face declining access to services and an eroding social fabric, as their populations shrink due to out-migration to the city and a limited influx of young people.

Changes in farm structures have contributed to higher efficiency of farm operations, increases in average yield and increased food security for a growing EU population. On the other hand, changes in farm structure have made it more difficult for smaller farms to compete. Meanwhile, larger and more specialized farms have been able to increase their income, while also being vulnerable to larger risks.

These changes in farm structures also have important implications for the environment. The move from smaller, more diverse farms to larger, mono-crop farms has important consequences for biodiversity. Moreover, the intensification of agriculture increases the ecological risks related to use of agricultural inputs and requires a higher energy demand per product translating in more GHG emissions per hectare.

CHALLENGES – NEEDS FOR R&I STRATEGIES

While the trend of changing farm structures has contributed to increased food security and higher farmer income, there are important trade-offs with the social and environmental impacts of larger, more specialized and intensified farms. In order to address these negative externalities of changing farm structures, focus points of research and innovation could be around the requirements for establishing more resource-smart food systems with lower environmental impact. Another point of research interest could be investigating the role of diversification in reviving rural communities and improving the resilience of the EU food system.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

AGRICULTURAL POLLUTION

CHALLENGE/TREND

Agriculture is a significant source of greenhouse gas emission and, due to excessive and sometimes improper use of fertilizers and pesticides, has led to a degradation of soil and water quality. Improper management of agricultural waste has contributed to local and regional air pollution. Measures that keep pollutants out of the air, water, soil, and food have helped to benefit both farmers and consumers at a time when citizens and governments around the world are seeking to ensure that agricultural development is sustainable.

SHORT DESCRIPTION

Food production in the EU has a range of environmental impacts. Farming activities contribute to air and soil pollution. Agriculture has been declared as the third largest source for pond, lake, and reservoir pollution as it causes disturbance of the rivers and streams.

Undue application of nitrogen- and phosphorus-based fertilizers on agricultural lands has led to the enrichment of these nutrients in soil, surface, and groundwater leading to pollution. Meanwhile, GHG emissions from agricultural practices contributed to climate change.

The current issues of agricultural pollution can be solved by practices like agricultural waste management, pest management, and manure recycling. Proper planning and decisions at government level are required to solve the issue [1].

The climate impact of agriculture can be addressed in two ways. One way is through mitigation of the agricultural contribution to climate change, for example through designing a less resource-intensive and more circular food system. Another way is through adaptation, through better management of agricultural risks associated with increasing climate variability and extreme events [2].

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DEVELOPMENT-DYNAMICS AND DRIVERS

The increasing use of energy and resources for agricultural production has a range of impacts on the environment. First, food production has negative effects on water, air and soil quality, mainly related to nutrient losses and emissions of pesticides. Second, these forms of pollution, combined which agriculture-related changes in land use and ecosystems, have a damaging effect on terrestrial and aquatic biodiversity. Finally, the GHG emissions related to agricultural production are responsible for their contribution to climate change.

In the EU context, agricultural pollution is in large part related to three challenges [3]:

- While open burning of agricultural residues is banned under EU regulation, many member states continue to report substantial emissions from this category.
- The application of mineral fertilizers continues to have a damaging impact on air and water quality, contributing to 20% of NH emissions. Over the past two decades, water pollution from agriculture decreased in EU countries.
- Manure from livestock contributes to a significant part of air and water pollution, while also contributing to a large portion of agriculture-related GHG emissions.

CONSEQUENCES ON FNS / SOCIETY

Apart from the before mentioned impacts on soil and water quality and issues around biodiversity, airborne diseases and cancers are major health issues faced by farm workers. They face injuries, illnesses, and fatalities due to physical exertion, contact with animals, use of machinery, and a high rate of exposure to toxic materials [4].

Although regulatory approaches have been taken in order to prevent occupational and environmental health hazards caused due to agricultural practices, the present conditions show that there is still a need for research and awareness of agricultural health and safety [1].

CHALLENGES – NEEDS FOR R&I STRATEGIES

Tackling agricultural pollution is not a straightforward task, however. Agricultural pollutants are numerous, and they emanate from many different and often diffuse sources. Field runoff from millions of farms, drugs and pathogens, organic matter, particulate matter, toxic compounds, and greenhouse gases are only a few examples. In addition, many of these pollutants are undetectable to the senses. Further complicating matters is the fact that agriculture is both a victim and a source of pollution, all of which implies that solutions are complex and need to be multifaceted [4, 5, 6, 7].

For the contribution of agriculture to climate change, an integrated impact assessment of climate change throughout the whole food chain is needed. Research-based strategies could contribute to direct reductions of greenhouse gas (GHG) emissions through carbon sequestration, fossil fuel energy substitution and mitigation of N2O and CH4 emissions by the agriculture and forestry sectors, while reducing GHG emissions per unit area and per unit product associated with land use change [8].

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

BIODIVERSITY LOSS

CHALLENGE

The biodiversity of natural ecosystems provides important, although largely unvalued, services (e.g. food provisioning, water purification, flood and drought control, nutrient cycling, and climate regulation) to both human populations and the environment. At a global level, as well as in most regions, biodiversity has been declining for decades. Human intervention in the biosphere is leading to a loss of biological diversity. If the destruction of ecosystems and related services will not be addressed sustainably, losses will be irreversible. Moreover, certain benefits from ecosystems might be lost completely.

SHORT DESCRIPTION

According to the Convention on Biological Diversity, biodiversity is the variability among living organsims from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Article 2, CBD, 1992 [1]).

Historically, land use change and the conversion of habitat to other land uses, notably for agricultural production, is a main driver of biodiversity loss, together with pollution, overexploitation of natural resources by overcropping, overfishing or overhunting, invasive alien species and, increasingly, climate change. Globally and regionally, biodiversity including agrobiodiversity has been declining for decades.

The abundance of vertebrate animals and other species declined between 1970 and 2010: about 11% and 30%, respectively, have been lost, with significant variability across regions and habitats [2]. Marine biodiversity has also become increasingly endangered following the progressive overexploitation of marine fish stocks in recent decades. Today, the share of over-exploited fish stocks is above 30%, while under 20% of stocks are less than fully exploited. [3]

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DEVELOPMENT-DYNAMICS AND DRIVERS

Today, the speed of biodiversity loss is increasing worldwide. It can be measured by a decrease of individual species, groups of species or in numbers of individual organisms. Habitat loss is the most serious of all threats to biodiversity. It is often a consequence of human activities, such as urbanization, the increase in cultivated land and international trade. The latter as well as new migration patterns due to increasing temperatures (as an immediate result of climate change) are important causes for the introduction of non-native species and genetic stock, which can also become a major threat to biodiversity. Because there is often a lack of natural antagonists, new species can easily become invasive. The biodiversity of aquatic ecosystems (e.g. reefs) is incresaingly threatend by pollution. Aquatic ecosystems provide valuable services: transportation, recreation, resilience and water filtration.

In agricultural areas, genetic diversity has also declined: on the one hand because of the repeated planting of a limited number of varieties, the introduction of new commercial varieties and losses of old varieties; and on the other hand, because of the destruction of (rain)forests and wildlife habitats (e.g. for living, feeding, reproducing, hibernating, migrating through green corridors, etc.). Agricultural practices also influence terrestrial and aquatic biodiversity within and around agricultural fields. Poor management of irrigation systems can contribute to land degradation, causing salination and waterlogging of soils. Overgrazing and deforestation also contribute to land degradation. Fertilizers, pest control chemicals, tillage and even crop rotation have an impact on the biodiversity of agricultural ecosystems. Concering livestock, mainly highly productive breeds are raised for meat, milk and eggs. High-yielding breeds often need more intensive management and can have a predisposition to specific diseases. Consequently, in livestock production, antibiotics and other medication have often been used to prevent disease; a sideeffect of this practice is the spread of antibiotic resistance in humans and animals.

CONSEQUENCES ON FNS / SOCIETY

Many key ecosystem services provided by biodiversity, such as nutrient cycling in soils, pest regulation and pollination of crops and other plants, sustain agricultural productivity. Promoting a healthy functioning of ecosystems ensures the resilience of agriculture, so that it can meet the growing demands for food production. Loss of biodiversity usually results in a limited gene pool, which might lead to a decrease in resilience.

However, a reduction in agricultural productivity could lead to even more pressure for agricultural land. It has been argued that without the widespread use of effective and efficient existing technologies and without a technological breakthrough that will increase yields on existing farmland, the food necessary to meet the growing demand will have to come from the expansion of agriculture into new areas, causing again negative effects on biodiversity. The diversity of farming systems can also contribute to cultural values.

CHALLENGES – NEEDS FOR R&I STRATEGIES

It will be necessary to contribute to the implementation of the Sustainable Development Goal 15 adopted in September 2015. (SDG 15 "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss"). All targets of this goal are relevant for biodiversity research. This includes also questions related to the diversification of gene pools, the restoration of “near-to-nature” habitats, governance of ecosystem services, prevention of “lock-in” into technologies that lead to ecosystem services degradation, and the ban of massive use of toxins (as present in many pesticides).

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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

TRANSBOUNDARY PESTS AND DISEASES

CHALLENGE/TREND

Food security is threatened by an alarming increase in the number of outbreaks of transboundary pests and diseases of plants and animals. These pests and diseases jeopardize food security and have broad economic, social and environmental impacts as they spread across national borders. The increase in zoonotic diseases running along with an increase in resistance to drugs, such as antibiotics, increase the threat to both humans and nature and thereby influence FNS. [1]

SHORT DESCRIPTION

Transboundary crop and animal diseases can spread across national borders causing high rates of illness and death since the diseases are highly contagious. Serious outbreak risk increases as more people, animals, plants and agricultural products move through many nations and as the animal production systems intensify. Food security and full economic potential in livestock sectors are weakened by the threat of transboundary animal diseases. Transboundary animal diseases such as bovine spongiform encephalopathy and highly pathogenic avian influenza have created several pandemics around the world when these diseases emerged or re-emerged [1].

Climate change is, in part, responsible for food chain emergencies arising from transboundary threats. However, while there is clear evidence that climate change is altering the distribution of animal and plant pests and diseases, the full effects are difficult to predict.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Intensification of agricultural production systems, rapid growth in international trade and more frequent international travel provide substantial risks concerning the spread of plants and animals across international borders. Consequently, the spread of transboundary plant pests, animal diseases and invasive species has increased dramatically in recent years. Reduced resilience in the production systems due to decades of agricultural intensification, has also played a part. Climate change will further heighten these risks. Climate change and change in land cover, such as deforestation and desertification, can make plants and animals more vulnerable to pests and diseases. Changes in temperature, moisture levels and concentrations of atmospheric gases can stimulate the growth and generation rates of plants, fungi and insects, altering the interactions between pests, their natural enemies and their hosts. Some of the most dramatic effects of climate change on transboundary animal diseases are likely to be seen among insect vectors, such as mosquitoes, midges, ticks, fleas and sand flies, and the viruses they carry. Because of broadening of areas with favourable climatic conditions for the pests, newly introduced pests can survive and settle in areas where they have not been a threat before, as the local climate allows for reproduction and hibernation.

CONSEQUENCES ON FNS / SOCIETY

Transboundary plant pests and diseases can easily spread to several countries and reach epidemic proportions. They affect food crops and can cause significant losses to farmers and threaten food security. For example, serious socioeconomic consequences can arise from transboundary diseases, such as regional and international livestock market disruptions. Transboundary animal diseases are a constant threat to livestock keepers' livelihood which is even more detrimental in low-and-middle-income countries. [1]

The advent of new pests can change the composition of the existing species community and colonise new niches of replace known and manageable species. New strategies might become necessary to manage the new pests.

The potential impact of animal diseases on human health is magnified further by increasing levels of resistance in bacteria, parasites, viruses and fungi to antimicrobial drugs, such as antibiotics, antifungals, antivirals, antimalarials and anthelmintics.

A change of the industrialized mode of food production might be a necessary consequence in the long run. This includes the management of smaller units of land with a greater variety of crops as well as more robust breeds of animals that are less susceptible to diseases. However, in the short term, in the presence of infections farmers might be more inclined to turn towards controlled conditions such as indoor animal husbandry.

CHALLENGES – NEEDS FOR R&I STRATEGIES

To be able to better deal with transboundary pests and diseases it is important to study the biology and transmission routes of the pests in more depths and gain more information on the pests. Coping strategies of former farmer generations might also shed light on feasible strategies, such as promotion of natural enemies or planting non-susceptible crops or breeds. Robust breeds are needed in the short term, even if they do not provide the crop yields of conventionally used breeds.

National surveillance systems need to be installed using also modern technologies such as drones with sensors and develop standard operating procedures to improve information sharing between countries. Authorities in charge need to be appointed. Early warning systems need to be developed and put in place on the national and regional levels.

Countries concerned (especially developing countries) need to be provided with the technical equipment and support necessary for surveillance and assessments of the infestation levels, damage, etc.

EXAMPLE REFERENCES

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

ORGANIC FARMING

TREND

A number of studies draw relations between soil and plant health, food crop nutritional quality, and human health and showed effects on nutrients, fat, vitamins, environment, and so on of organic farming. Recent evidence suggests that organically grown fruits and vegetables contain higher levels of phytochemicals, possibly linked to greater plant stress, rhizosphere microbial communities, and/or lower available nitrogen.

SHORT DESCRIPTION

Organic farming applies agro-ecological principles that benefit the sustainability of the farming system. It utilizes carbon-based amendments, diverse crop rotations, and cover crops to build soil fertility. These practices increase biologically available soil organic matter and beneficial soil microbe and invertebrate activities, improve soil physical properties, reduce disease potential, and increase plant health. A number of comparative studies showed lower nitrate contents and less pesticide residues, but usually higher levels of vitamin C and phenolic compounds in organic plant products, as well as higher levels of omega-3 fatty acids and conjugated linoleic acid in milk from organically raised animals.

Organic farming systems are often more intensive in land use than conventional farming systems, resulting in lower yields (ton/ha). To date, comparisons of nutrient content between organic and conventional foods have been inconsistent. But the overlap in management practices among farming systems make broad generalizations difficult. Moreover, environmental and crop species and/or cultivar interactions may exert stronger effects than management. [1,2]

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DEVELOPMENT-DYNAMICS AND DRIVERS

Different trends and drivers influence the rise of organic farming. Consumers have become more concerned about the quality of food they eat. Organic farming is considered to generate healthier farm products, as they contain fewer chemical residues. Moreover, purchasing power among elite consumers is rising. Distribution channels are increasingly mainstream: organic food is more and more present in supermarkets. Labelling schemes have improved transparency, but large differences in consumer trust persist. Shifting from conventional to organic farming systems is costly and not without risks. However, many organic and agroecological practices can be adopted more widely, not just in organic systems.

CONSEQUENCES ON FNS / SOCIETY

Shifts towards organic farming has a range of different social and environmental implications. Organic farming has the potential to build trust of consumers in supply chains, although many misconceptions persist about organic farming. Also, the agro-ecological proofing of agriculture is needed to safeguard environmental sustainability. However, at the current structure of demand, a wider shift to organic systems might form a threat to global food security because of its higher land intensity. As organic farming products enter the large supermarket chains, organic farms are becoming more dependent on the big retail corporations. To reduce this dependence and create a form of community-supported agriculture, organic farming could adopt small-scale retail structures and alternative distribution channels.

CHALLENGES – NEEDS FOR R&I STRATEGIES

A shift to organic farming could be connected to a drive for integrating more agro-ecological principles into the food productions systems. This encompasses different challenges and needs that could inform R&I strategies. One challenge is related to the fact that production costs of organic farming are often higher than for conventional farming; another is that organic production systems, in particular in horticulture, are less conducive with demands from buyers to standardize produce in terms of size and shape. Finally, organic farming methods often differ between countries, leading to different standards across the world. R&I strategies could be developed that address these challenges. Research needs can be identified in the development of mixed food systems, increasing yields using a combination of organic fertilizer and integrated pest management.

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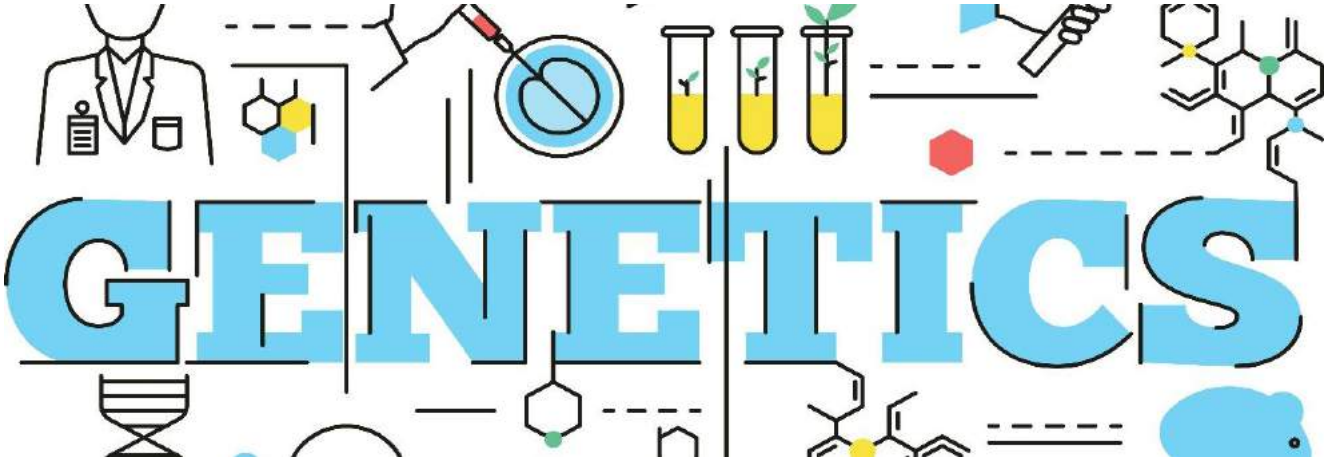
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

GENOME ENGINEERING

TREND



Advances in genome engineering offer immense potential for modern animal and plant breeding. New possibilities include building plant resistance to pests, diseases or environmental threats (e.g. draught), creating biopesticides, increasing throughput or prolonging shelf life. One of the most potential methods is the CRISPR-cas9 gene editing tool with unprecedented precision. Since the mid-1990s, the release of GMOs (genetically modified organisms) into the environment and the marketing of foods derived from GM (genetically modified) crops has resulted in a scientific and public debate.

SHORT DESCRIPTION

Genome engineering is a powerful tool for plant and animal breeding, offering breeders the potential to wipe out genetic disease, improve drought or other resistance of plants, boost nutrient efficiency, or prolong shelf life. Various methods have been developed that need to be regulated (e.g. cisgenesis, transgenesis, CRISPR-cas9, RNA interference). These methods aim at quickly and easily edit the DNA of any living species in order to enhance certain features. Thus genetic or genome engineering can contribute to [1]:

- Genomic selection and marker assisted selection of plants and animals and of genetic resources, innovative use of gene technology and new techniques like gene editing;
- High throughput phenotyping of plants and animals;
- Environmental genomics: barcoding of species, new generation sequencing applied to animal and plant health (emerging diseases); and
- Meta-omics (including metagenomics of soils, rumen of ruminants etc.), environmental genomics, metabolic profiling;

Despite the potential benefits of genetic engineering in agriculture to improve the quality and the reliability of the food supply, since the beginning, public and scientific concerns have been raised in many parts of the world about environmental and food safety of GM crops [2].

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DEVELOPMENT-DYNAMICS AND DRIVERS

Technological advancements in genome engineering have spurred the development of new techniques that can be used for more exact, less expensive, and less time-consuming breeding of plants, animals and microorganisms to obtain durable resistance, improved abiotic stress tolerance and other important quality traits. These 'New Breeding Techniques' (NBT) comprise a diverse range of techniques as regards their approach, methodology and unique characteristics. Some of the NBT result in organisms that contain only point mutations and are practically indistinguishable from varieties bred through conventional breeding methods or resulting from spontaneous mutations. While some of these techniques can only be applied for plant breeding, others, in particular the recent techniques of genome editing, are applied in plants, animals and microorganisms. [2]

Genome-editing techniques (including e.g. zinc finger nucleases (ZFN) or CRISPR/Cas) enable a precise alteration of a DNA sequence in a cell, or achieve random changes at precise locations. Genome editing is applied to breed e.g. herbicide-resistance in crops, non-browning mushrooms, high yield rice or hornless milk cows, improved muscle growth in animals, or farm animals with var. resistances to diseases. **Cisgenesis and intragenesis** are techniques that introduce genetic material from same or sexually compatible species. The latter may be a closely related cultivated species or related wild species. These techniques are used, to develop disease resistant apples or potatoes. In principle, products similar to cisgenic products, but not to intragenic products, could be obtained by conventional breeding, although the location of the inserted gene would differ for each cisgenic organism due to random insertion**. Epigenetic modifications** (known as RNA-dependent DNA methylation) silence specific genes in a way that will usually disappear after several generations (e.g. delayed tomato ripening, insecticide production in potatoes). **Agro-infiltration** delivers genetic material to a plant transiently, for a maximum of one generation (e.g. vaccine, antibody production). It can be used to screen for plants with valuable phenotypes that can then be used in breeding programmes. **Reverse breeding**, the silencing of genes in charge of genetic recombination in the sexual reproduction process, is used to create hybrids in e.g. maize or fruit trees. **Grafting techniques** are applied to combine a non-GMO scion with a GMO rootstock (or vice versa) to develop disease resistant fruit trees [2, 3].

CONSEQUENCES ON FNS / SOCIETY

NBT are considered a major advance in biotechnology, offering unprecedented benefits for agriculture, sustainability and the economy, but also for human health. In agriculture, the potential benefits include opportunities for improved efficiency, greater productivity, broader varietal repertoires. Environmental applications of gene editing technologies could enable novel approaches to conservation, bioremediation, the control of invasive species, and the protection of biodiversity. In addition, gene editing technologies might also lead to new cures and therapies for genetic diseases in human medicine. However, as genome editing can also produce unintended off-target effects in plants, animals and microorganisms, there are also significant policy challenges at the national and international level related to the governance of the new genome engineering techniques, given the wide range of potential applications. A few plants have already been generated with NBT and are already close to or at the stage of field trials or which are already commercialised (e.g. in Canada). [2]

CHALLENGES – NEEDS FOR R&I STRATEGIES

Regulatory measures need to be adapted and public trust in regulatory institutions need to be fostered. Conventional risk analysis frameworks may need to be adjusted or enlarged, to face challenges and new questions presented by genome engineering technologies. Issues surrounding the intellectual property protection of gene editing technologies deserves further observation. [4] Genetic alterations produced by NBT can lead to potential environmental and health impacts, as there is increasing evidence of 'off-target' effects. The effects on the wholesomeness as a foodstuff and how the organism interacts with the environment are far from being precisely known. Such effects could have implications for food, feed and environmental safety if they increase levels of toxic compounds, reduce levels of nutritional compounds or even produce new allergens.

EXAMPLE REFERENCES

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

BIO-FORTIFICATION

TREND

Fortification is the practice of deliberately increasing the content of an essential micronutrient, i.e. vitamins and minerals (including trace elements) in a food, to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to health. Biofortification is the process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding, or modern biotechnology. [1]

SHORT DESCRIPTION

Biofortification differs from conventional fortification in that biofortification aims to increase nutrient levels in crops during plant growth rather than through manual means during processing of the crops. Biofortification may therefore present a way to reach populations where supplementation and conventional fortification activities may be difficult to implement and/or limited.

Examples of biofortification projects include:

- iron-biofortification of rice, beans, sweet potato, cassava and legumes;
- zinc-biofortification of wheat, rice, beans, sweet potato and maize;
- provitamin A carotenoid-biofortification of sweet potato, maize and cassava; and
- amino acid and protein-biofortification of sorghum and cassava. [1,2]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

Many soils in developing countries (e.g. in sub-Saharan Africa) are characterized by multiple nutrient deficiencies including macronutrients (N, P, K, secondary nutrients S, Ca and Mg), as well as micronutrients (Zn, Fe, Cu, Mn, Mo and B). Insufficient micronutrient availability in soils cause low crop productivity and poor nutritional quality of the crops, and may lead to insufficient micronutrient uptake. [4]

Worldwide, more than two billion people suffer from micronutrient deficiencies (hidden hunger), which is likely to increase the risk of stunting, anaemia, blindness, infectious diseases and even death, especially among women and young children. Such micronutrient deficiencies occur when intake and absorption of vitamins and minerals are too low to sustain good health and development. Although a lot of effort has been done in agricultural research for developing countries to increase production and availability of calorically dense staple crops during the last decades, sufficient micronutrient supply could not be ensured for large parts of the especially poor population. Because of the high prices of micronutrient-rich crops such as vegetables, legumes and animal products compared to staple crops, they are often not affordable to the poor.

Micronutrient deficiencies can be alleviated by either improving the dietary diversity through a change in the eating behaviour or by consuming micronutrient supplements or fortified food. Industrial fortification of food improves the nutrient quality of food by adding micronutrients to the food during the processing stage. This is a rather costly and usually not sustainable approach, as many of the poorest families living in remote rural areas that are most affected by hidden hunger may not have access to commercially processed foods.

An alternative approach is biofortification of crops (e.g. maize, cassava, sweet potato, beans, pearl millet, rice and wheat), where the content and bioavailability of essential nutrients of crops is increased at the agricultural production stage through agronomic practices (e.g. application of micronutrient-enriched fertilizers) and by using conventional and transgenic plant breeding techniques. Currently, substantial efforts are being made in increasing iron, zinc and provitamin A, as deficiencies of these nutrients are most prevalent worldwide. [3]

CONSEQUENCES ON FNS / SOCIETY

Sofar, biofortified crops are cultivated in more than 30 countries. Biofortified crops are primarily aimed at reaching the population of remote rural areas in developing countries who may have limited access to diverse diets or other micronutrient interventions, where hidden hunger is most prevalent. Once the newly bred biofortified crops have been established in the farming communities, farmers can save and share seeds, roots and tubers and cultivate them in the following years, which will ensure micronutrient-rich food year after year. In addition, it is expected that market surpluses will also reach urban populations and complement fortification and supplementation programmes, which work best in urban areas. [3] Once developed, biofortified crops can be easily adapted to new environements and geographical regions, multiplying the orignal investments. Concerning agronomic biofortification, the application of micronutrient-enriched fertilizers is considered to have minimal negative environmental impact. However, the microelements can accumulate over time and become toxic. [4]

CHALLENGES – NEEDS FOR R&I STRATEGIES

For successful breeding of nutrient-rich crops, high nutrient density must be combined with high yields and high profitability. The micronutrient status of humans must be shown to improve when consuming the biofortified crops. Biofortified crops must be adopted by farmers and consumed by those suffering from micronutrient malnutrition in significant numbers. [4] Biofortification needs to be scaled up to improve nutrition globally and trials are needed to test the efficacy of biofortified crops for a wider range of age and gender groups, and to test the efficacy of consuming several different biofortified crops, each providing different vitamins and/or minerals.

EXAMPLE REFERENCES

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

INDOOR CULTIVATION SYSTEMS

TREND

Indoor (urban) farming technologies involve agricultural production in (multi-storey) buildings. Systems such as hydroponics or aquaponics grow plants in soil-less nutrient solutions. New technologies such as LED lights make production all year round possible and environmentally friendly. Further effect of these growing systems is the controlled conditions or the independence of access to soil.

SHORT DESCRIPTION

Vertical farming or high-rise farming is a proposed indoor, urban farming technology involving large-scale agricultural production in multi-story buildings. Hydroponics and aquaponics methods are tools to produce crops in soil-less nutrient solutions. [1]

These farming processes promise to eliminate external natural processes since crops will be grown under carefully selected and well-monitored conditions, ensuring an optimal growth rate for each species of plant and animal year-round. Furthermore, they reduce the need for fossil fuels to run machinery during the different stages of farming (i.e., plowing, applying fertilizer, seeding, weeding, harvesting).

Hydroponic culture - a soil-less cultivation technology with the application of nutrient medium and under controlled conditions - has become the fastest growing and second generation of crop production system in agricultural industry.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

Main global drivers fostering indoor cultivation systems are urbanization and the scarcity of resources (land). The decreasing trust food products and their origin and shifting expectattions regarding local and biological origin also supports this trend. Because of consumer demand for local food, short ways of distribution also support environmentally friendly production.

CONSEQUENCES ON FNS IN SOCIETY

Consequences on FNS (social, economic, ecological)

In the **economic** domain, indoor cultivation systems may create new jobs in regional/urban production and distribution sectors, which may, however, come at the expense of loss of jobs in primary production.

In the **social** realm, new indoor cultivation technologies may contribute to empowerment of society at large in terms of more awareness of the origin of the food on the plate).

In an **ecological** perspective, energy demand may decrease due to new production technologies (e.g. LEDs) and shift energy sources (from fossil to alternative sources e.g. Photovoltaic). Water demand may go down due to improved water recycling technologies. In terms of health, a key question is whether these products will have the same composition (quality) as the ones outside these structures?

CHALLENGES – NEEDS FOR R&I STRATEGIES

To date it is not clear what it takes to bring harvest and nutritional value of these food products in desired level (and what level do we need). Moreover, the question arises as to business models to finance cost of these expensive systems.

There is a need for adequate diffusion and embedding strategies (upscaling) of niche production facilitites and social and/or regulatory innovations to co-evolve with technological innovations.

If not coverd by regulation and standards, indoor cultivation could potentially become a risk for food safety.

EXAMPLE REFERENCES

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

URBAN AGRICULTURE / URBAN FARMING

TREND

Urban agriculture can be defined as the growing of plants and the raising of animals within and around cities. The most striking feature of urban agriculture, which distinguishes it from rural agriculture, is that it is integrated into the urban economic and ecological system: urban agriculture is embedded in - and interacting with the urban ecosystem.

SHORT DESCRIPTION

Urban agriculture includes food products, from different types of crops (grains, root crops, vegetables, mushrooms, fruits) and animals (poultry, rabbits, goats, sheep, cattle, pigs, guinea pigs, fish, etc.) as well as non-food products (like aromatic and medicinal herbs, ornamental plants, tree products, etc.) or combinations of these. Often the more perishable and relatively high-valued vegetables and animal products and by-products are favoured. Production units in urban agriculture in general tend to be more specialised than rural enterprises, and exchanges are taking place across production units.

Examples include home gardening, community gardening, institutional gardens at schools and hospitals, and open field farming at micro scale with low levels of investment, but also include larger scale enterprises with sophisticated high-tech aquaponics or in-door farming systems. A multi stakeholder approach should involve various sectors and disciplines: agriculture, health, waste management, community development, parks and nature management, among others.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

The rapid urbanization that is taking place goes together with a rapid increase in urban poverty and urban food insecurity. By 2020 the developing countries of Africa, Asia, and Latin America will be home to some 75% of all urban dwellers, and to eight of the anticipated nine mega-cities with populations higher than 20 million. It is expected that by 2020, 85% of the poor in Latin America, and about 40-45% of the poor in Africa and Asia will be concentrated in towns and cities.

Next to food security, urban agriculture contributes to local economic development, poverty alleviation and social inclusion of the urban poor and women in par-ticular, as well as to the greening of the city and the productive reuse of urban wastes. The importance of urban agriculture is increasingly recognised by international organisations like UN-Habitat and FAO (World Food and Agriculture Organisation).

CONSEQUENCES ON FNS / SOCIETY

The **social** perspective is mainly (but not exclusively) associated with subsistence oriented types of urban agriculture that form part of the livelihood strategies of urban low-income households with a focus on producing food and medicinal plants for home consumption. As a result, the family expenses on food and medicines are reduced and some cash is generated from sales of surpluses. These households seek out multiple additional income sources for their survival. Examples include home gardening, community gardening, institutional gardens at schools and hospitals, and open field farming at micro scale with low levels of investment. These systems show little direct profitability but have important social impacts such as enhanced food security, social inclusion, poverty alleviation, community development etc. [1]

The **economic** perspective is particularly related to market oriented types of urban agriculture. Activities usually involve small-scale family-based enterprises and sometimes larger scale entrepreneurial farms run by private investors or producer associations. New economic models such as the sale of local food with little or without intermediaries and the organisation of cooperatives are emerging. The activities not only include food production (e.g. irrigated vegetable production, stall-fed dairy production) but also non-food products (e.g. medicinal and aromatic herbs, flowers, ornamental plants). These commercial farms are associated with small-scale and larger enterprises involved in delivery of inputs (such as seed, compost, fodder, agro-chemicals) and the processing and marketing of agricultural products. [1]

The **ecological** perspective refers mainly to types of urban agriculture that have a multi- functional character: Besides provision of food and generating income they can play a role in environmental management for example, through nutrient recycling via decentralised composting and reuse of organic wastes and wastewater. They can also provide other services demanded by urban citizens: urban greening, im-provement of the urban climate, keeping buffer zones and flood plains free from construction, provision of opportunities for leisure and recreational activities, storm water storage and flood prevention and others. [1]

CHALLENGES – NEEDS FOR R&I STRATEGIES

To enable urban and peri-urban agriculture it is essential to have all parts of the system working closely together and to have them interlinked with each other. RUAF Foundation [1] lists some of these points as adopting agro-ecological production methods, linking up with eco-sanitation and decentralised sustainable waste management systems, as well as becoming part of the planning and management of parks, nature reserves and recreational services. Agriculture needs to work closely with city planning and waste management, with stakeholder participation and integration to reach a sustainable functional system. Also eductation and sensibilistation of urban citizens and investment into access for tailor made solutions are necessary to consider.

EXAMPLE REFERENCES

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

FOOD FROM THE SEA

TREND

The ocean contains 97% of the planet's water. It provides seafood, which is the primary source of animal protein in the diets of approximately 1 billion people.

According to FAO, food supply will have to increase 60% by 2050 to meet the demands of a projected population of 9 billion.

If sustainably managed, the ocean could contribute to food security and alleviate pressures on land based food production.

SHORT DESCRIPTION

In light of the expected increase in world population to 2050 and demand for food, the ocean clearly has an important part to play in supplementing the food supplies generated by agriculture.

In many parts of the world, marine produce will continue to be a prime source of protein and vitamins for millions of people, especially as the growing middle classes shift their spending to high-end protein products.

However, the ocean's capacity to perform that role is increasingly undermined by overfishing and depleted stocks in many parts of the world as well as by the impacts of land-based pollution, not least the run-off of fertilisers and agricultural waste into coastal and estuary zones, which threatens marine life habitats, fish stocks, molluscs and so on.

Growth in global capture fisheries is therefore expected to remain more or less flat over the next ten years or so.

The increase in world demand for seafood will need to be absorbed by a significant expansion in aquaculture, especially in marine aquaculture.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

Food from the sea is, of course, not disconnected from the land. Many of the drivers, consequenses and challenges are the same as those facing terrestrial food production. There are, however, several aspects which are either unique to the ocean or at least require a different approach.

Global food supplies are in some cases threatened by an overexploitation of resources. Concerning fish stocks, for example, despite the implementation of recovery plans, overfishing has already seen the collapse of high-profile species. Today almost 30% of global fish stocks are judged to be fished at a biologically unsustainable level, i.e. overfished.

Finfish aquaculture still depends on fishmeal from a combination of small pelagic fish, by-product of fish processing and soy. Increase in fishmeal and soymeal prices is reflecting the limits to fishmeal production and the increased competition, such as from biofuels. The globalised markets for fishmeal are capable of adding enormous pressures on local resources and resulting in sequential exploitation. The interactions between marine fisheries, aquaculture and land-based food production need to be considered in terms of maximising production while ensuring environmental protection at all scales.

It is often the case that fishing activity takes place alongside other industrial activity at sea such as energy generation, transport and tourism. These activities not only compete for space, but also interfere with each other through the release of contaminants, which can affect both the health of food webs and of the humans relying on them, or through the physical damage to essential habitats. More holistic ecosystem-based management practices are evolving to balance the needs of the different industries.

CONSEQUENCES ON FNS / SOCIETY

As incomes across the world increase in coming years, changes in dietary preferences are also expected to remain a key driver, notably with increasing demands on high-value animal protein, including fish and other seafood products.

CHALLENGES – NEEDS FOR R&I STRATEGIES

The accumulated impacts of climate change on the marine environment will lead to changes in ocean currents, seawater temperature and productivity in the photic layer of specific ocean areas. This could potentially trigger changes in the food-web structures and species interactions including regime shifts.

Marine aquaculture is building on advances in biotechnology to improve fish health and welfare and reduce dependence on wild fish catches for feed.

It is estimated that by-products may constitute as much as 70% of fish and shellfish after industrial processing. It is no longer ethically, environmentally or economically feasible to treat this as “waste”, but instead as a new bioresource. Valorisation of currently underused components of the catch is needed to optimally use biomass for human benefit.

EXAMPLE REFERENCES

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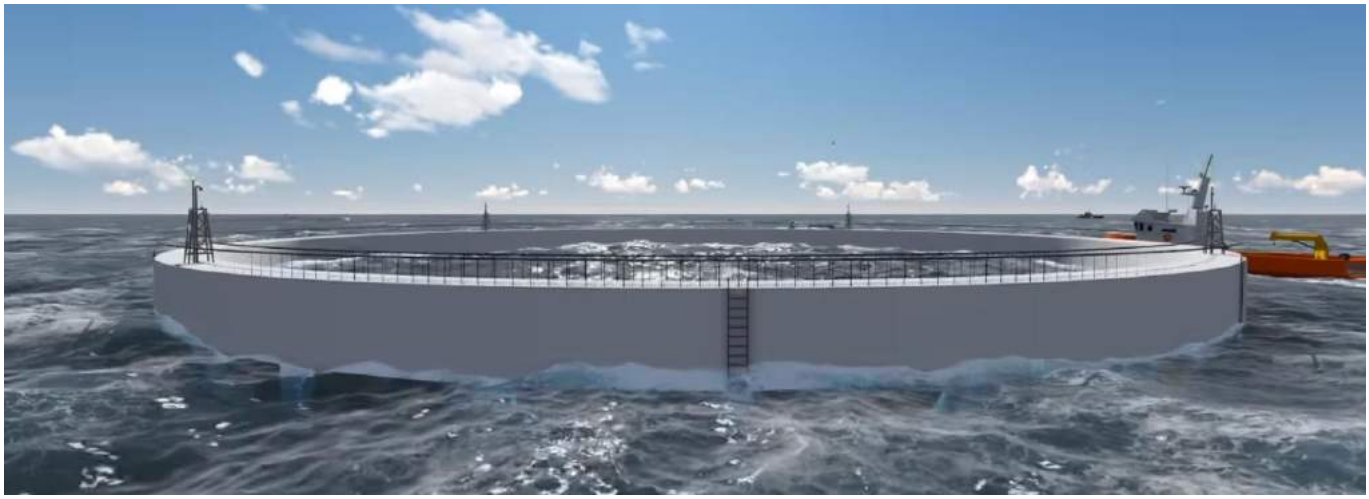
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

CLOSING THE LOOP IN AQUACULTURE

TREND



The challenges that (finfish) aquaculture is facing has sparked interest for a gradual transition from open to (semi-) closed aquaculture facilities. Most challenges affecting the aquaculture sector can be addressed by fully-closed systems as there is a barrier between the cultivated organisms and the natural environment. These systems can either be land-based or marine, as long as there is no continuous water exchange between the cultivation system and the natural environment. Although requiring significant investments, the transition from open to closed aquaculture has been demonstrated to be economically viable.

SHORT DESCRIPTION

Aquaculture is one of the fastest growing food sectors with more than a tenfold increase in production over the past 25 years, so far keeping up with the growing fish demand. However, this increase in production is mainly due to developments of the Asian aquaculture sector, with only a slight increase in production of the European sector. According to the Scientific Advice Mechanism (SAM), there is a great potential for expansion of the European mariculture by technological innovations, especially at the lower trophic levels (herbivorous fish, shellfish and aquatic plants). These technological innovations should focus on the sustainable challenges that are currently limiting expansion of the sector.

The challenges that (finfish) aquaculture is momentarily facing has sparked interest for a gradual transition from open to (semi-) closed aquaculture facilities. The challenges facing aquaculture in pens or net cages include sea lice, escapees, nutrient pollution and disease transmission from cultivated to wild organisms. Apart from being more environmental friendly, the closed aquaculture system also allows for a more efficient use of waste water, for example, through recirculating aquaculture systems (RAS) or integrated multi-trophic aquaculture (IMTA). Innovations like closed aquaculture systems, RAS or IMTA are not only beneficial to the sustainability of the cultivation process but also contribute to the competitiveness of the sector by increasing the efficiency of the production cycle and reducing the amount of required fish feed.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

The main drivers for the transition to (semi-) closed aquaculture has an economic, environmental and ethical aspect. The economic aspect is the decrease in yield due to sea lice and escapees and the high annual cost of control measures. The environmental aspect is the genetic impact of cultivated organisms (mainly finfish) on wild stocks and the nutrient pollution in the natural environment. And finally, the ethical aspect is the animal welfare in regard to the control measures of sea lice. These last two drivers are especially important concerning the reputation of the aquaculture industry and the social acceptance of their product.

Another factor is that the closed aquaculture system also allows for a more efficient use of waste water. With RAS the water is re-used in the cultivation infrastructure after passing through a filtering step. IMTA is the co-cultivation of fed species (e.g. finfish or shrimp) together with extractive species (e.g. mussels or oysters) and aquatic plants, which may feed on the effluents generated by the fed species. With both approaches (RAS and IMTA), any nutrients present in the waste water are recirculated to maximize the nutritional value of the fish feed.

CONSEQUENCES ON FNS / SOCIETY

Closed aquaculture, either land-based or marine, would be beneficial to the stability of the aquaculture's yield, thereby delivering a more reliable production in the long-term. With this development, the influence of neighboring farms in terms of parasites and pollution can be reduced which facilitates a higher intensity production within a region if spatial planning allows.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Due to the high investments in the cultivation infrastructure, closed aquaculture systems were often regarded as economically unviable. However, if the present high loss due to parasites and escapees and the costly control measures are included in this cost-benefit analysis, closed aquaculture systems have the potential to be economically successful. This finding is supported by the trend that most organizations involved in aquaculture are investing or are interested in the transition from open to closed cultivation facilities. Apart from the economic aspect, organizations involved in this transition should exchange best-practices concerning filtering of the generated effluents before discharge in the natural environment; not only to reduce nutrient pollution but also to prevent the spread of parasites and pathogens.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

PERMACULTURE

CHALLENGE/TREND

Permaculture strives to design sustainable agricultural systems and human habitats that mimic the patterns and relationships found in natural ecosystems.

SHORT DESCRIPTION

Permaculture is an integrated and functional approach developed for designing sustainable land use systems and guided by ecological principles. It integrates land, resources, people and the environment through mutually beneficial synergies – imitating the no waste, closed loop systems seen in diverse natural systems. Permaculture studies and applies holistic solutions that are applicable in rural and urban contexts at any scale. It is a multidisciplinary toolbox including agriculture, water harvesting and hydrology, energy, natural building, forestry, waste management, animal systems, aquaculture, appropriate technology, economics and community development.

Permaculture looks at everything that people do in life and tries to make it sustainable for many generations to come. Much of this sustainability is achieved by imitating what can be seen in nature.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

The term “permaculture” was coined by Bill Mollison and David Holmgren in the mid-1970s from the words “permanent” and “agriculture” to describe “the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems. It is the harmonious integration of landscape and people — providing their food, energy, shelter, and other material and non-material needs in a sustainable way”. [2] The idea for permaculture was inspired by broad environmental concerns with in the 1970s ongoing ecological developments while focusing specifically on the threat of energy scarcity for energy-intensive agricultural systems. The philosophy behind permaculture is one of working with, rather than against, nature; by observing and learning from the environment, by looking at systems in all their functions, rather than exploiting the agricultural systems only for yield. [1] Permaculture goes beyond an agricultural system, it is a system of living. The agricultural component of permaculture tries to design systems that mimic the way that natural systems work, such as forests. The design and use of perennial polycultures is a core theme of permaculture. Components of organic farming are a part of permaculture, but do not cover the whole concept of permaculture. [1]

Practical application of permaculture is characterized by a set of ecological and systems-thinking principles for design that are based on environmental principles and ethics such as “earth repair” and “people care”. Its aims are to re-design the whole production process to decrease waste, work, and pollution, while increasing the fertility, biodiversity, and sustainability of agriculture and to integrate all the components of a human settlement such as building construction, farm layout, transportation, hydrology, energy management, as well as community relations. The approach emphasises (1) site specificity, including attention to microclimate; (2) interaction between components at multiple scales, from field-scale polycultures to agroecosystem-scale land use diversity; and (3) spatial configuration as a key driver of multiple functions. [3]

Significant drivers for the spread of the permaculture method are its optimistic focus on holistic and positive action, on personal responsibility, and on the simplicity of needed solutions. [3]

CONSEQUENCES ON FNS / SOCIETY

The permaculture concept has spread around the world and is now an international agroecological movement of individuals and groups in rich and poor countries. The permaculture movement communicates a distinctive worldview to new and potential participants and disseminates elements of practice and design through networks of practitioners and small institutes. The dissemination of permaculture is due to two basic patterns: a widely dispersed network of “itinerant teachers” and local/regional organizing based around “bioregional” cultures and the development of alternative economic and social institutions. [3]

The practitioners are contributing to a sustainable future by reorganising their lives and work around permaculture design principles. The small local changes created by them can directly and indirectly influence actions in the wider environment, organic agriculture, appropriate technology, communities and other movements for a sustainable world. *Key elements of the permaculture worldview include ideas about human–environment relations, a populist orientation to practice, and a model of social change. At the core of the permaculture worldview is the idea that—with the application of ecologically informed holistic planning and design—humans can meet their needs while increasing ecosystem health.* [3]

CHALLENGES – NEEDS FOR R&I STRATEGIES

Despite a high public profile, permaculture has remained relatively isolated from scientific research both in terms of a lack of scholarly research about permaculture and neglect within the permaculture literature of contemporary scientific perspectives. Among other reasons this is because of overreaching and oversimplifying claims, the lack of a clear definition and the absence of any systematic multisite assessment of permaculture's impacts. In addition, the idiosyncratic use of scientific and scientific-sounding terms has led some scientists to label permaculture as a pseudoscience. [3]

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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

3. FOOD PROCESSING

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

BLOCKCHAIN TECHNOLOGY FOR SECURE FOOD SUPPLY CHAIN

TREND

In an increasingly volatile market, the blockchain adds an extra level of security for the food industry. Companies who can utilise blockchains to instil transparency in their supply chains are well protected should another scandal hit the industry. Blockchain technology was developed as a decentralised ledger which records transactions and stores this information on a global network in a manner which prevents it being changed at a future point.

SHORT DESCRIPTION

Blockchain technology stores data in blocks, in chronological order, and due to what is considered a mathematical trapdoor data stored in such a way are impossible to alter or remove. Copies of the chain of blocks - hence the term blockchain - and thereby the information, are distributed among the participants in the network. The copies of the blockchain are then updated when a new block of information is added to the chain [1, 2].

Originally designed for financial applications blockchains can have a huge potential in the traceability of all supply chains including food supply chains. The most common applications are simply confirmation of the source of a product, but blockchain is also being used to ensure availability of production data, prevent food fraud, provide payment security, ensure regulatory compliance and provide safe access to markets for small and remote farmers [4].

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

A strong driver behind implementing blockchain technology is from production side in order to make the food supply chain tamper proof and to underpin possible food fraud. Big companies are thus gaining more control over their suppliers and subcontractors and increase the food security in their production chain.

Consumer demand in full traceability is growing stronger and blockchain technology seems to provide a relyable tool for food companies to meet this demand and thus strengthening customer loyalty for those companies who can consistently guarantee quality. Another driver is the increasing awareness of consumers in sustainability and transparency of products and companies. Information about environmental and social performance of suppliers and their products is sometimes available through different certifications (e.g. fair trade), but there is no information or certification on how the transportation of an eco-friendly product is executed. Linking blockchain with a smartphone application, possibly enabling scanning of barcodes through the camera, consumers can easily access information on producers and origin of raw material.

CONSEQUENCES ON FNS / SOCIETY

Bockchain technology brings huge advantages for every actor within the supply chain. For **food producers**, the blockchain means that any attempt to tamper with a food item as it moves through the supply chain can be immediately identified and prevented before the food ever reaches the retailer. Further, it allows farmers in remote regions enter the food supply chain and gaining direct access to retailers/producers. Big companies such as Wal-Mart Stores Inc. and International Business Machines Corp. have already engaged in this technology, more are joining in, including Nestle SA, Carrefour or Dole Food Co. Companies.

For **retailers**, if a potentially hazardous food product somehow makes it onto shelves, stores can identify and remove only the offending items, eliminating the need for costly batch recalls. **Logistically**, blockchain can speed up the movement of food through the supply chain network (critical for perishable goods), and also allows fast, targeted, removal of products that are not fit for consumption [4].

For **consumers**, the blockchain offers the transparency and openness needed to reassure them that the food they eat is exactly what the label says it is. The ability for consumers to identify high quality food is currently prohibited by information asymmetry. [2]

CHALLENGES – NEEDS FOR R&I STRATEGIES

To be able to implement the technology and successfully use it, there are of course challenges that have to be overcome: there are implementations costs and as with every supply chain process it works best if all participants are involved. For small companies or farmers it may be a huge step to keep up with the technical development and thus inequality could be created for those not able to afford or implement this technology. Standards are still evolving and some overarching authority is necessary to ensure the trust in the system.

Blockchain has a huge potential for food safety and traceability improving the transparency and reliability of the food chain, to improve market access and reduce food waste. Consumers still need to be motivated to make use of the possibilities for tracing food back along the supply chain. Further, the blockchain technology needs to be implemented transparently to ensure consumers and citizens understand its advantages and disadvantages and the impact on themselves.

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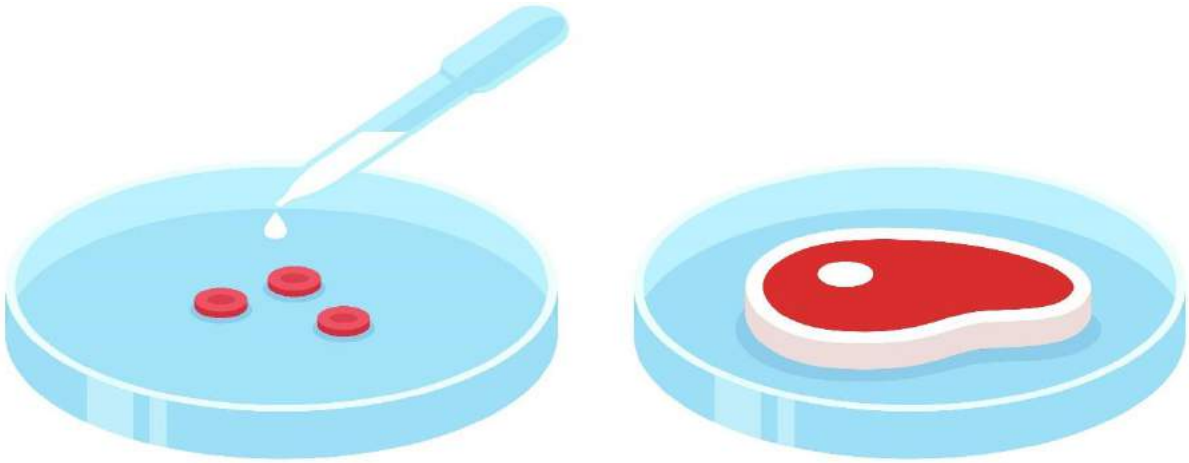
CULTURED / IN-VITRO MEAT

TREND



Cultured, lab-grown or *invitro* meat utilizes technology to produce meat from animal (stem) cells without killing the animal. As stem cells can be the source for pretty much every type of cell it might be possible to change the biochemical composition of meat to make it a healthier or specialized dietary product while also reducing concerns with animal welfare. Worldwide start-ups have already been formed to cultivate meat balls and other meat from animal (stem) cells since 2016.

SHORT DESCRIPTION

A proposed alternative to conventional meat production is cultured meat (also referred to as lab grown, clean or in-vitro meat). The production of cultured meat could enable novel products, enriched with more favourable saturated fat levels, by changing the biochemical composition of meat and leading to healthier or specialized diet products.

Additionally, concerns regarding animal welfare may be reduced with a meat alternative, such as cultured meat. Post (2014) indicated that for a meat alternative to be successful it must mimic real meat and have the ability to be produced in an efficient manner [4].

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DEVELOPMENT-DYNAMICS AND DRIVERS

Strong driver behind this trend is the increasing pressure on the livestock sector to meet the growing demand for high-value animal protein [6]. Also, livestock dominate agricultural land use by area and are a major source of greenhouse gases [1], more sustainable options are sought not only to contribute to CO_2 reduction but also to serve as marketing instrument.

An important driver in the development of cultured meat is the medical interest in tissue engineering [2]. Thus, breakthroughs in *in vitro* cultures to make it affordable open a door for new business opportunities. Start-up companies in this field can be found in the US and Europe, e.g. [5].

Carefully controlled conditions of culturing meat tissue could potentially minimise the spread of animal-borne diseases as well as reducing foodborne pathogens, such as Salmonella, campylobacter or E. coli, or the use of drugs, as antibiotics, by following hygienic procedures throughout the process [2].

Furthermore, a strong positive argument for cultured meat products is the prospect of avoiding animal suffering as producing cultured meat without the killing of animals as live animals as a source for the initial cells in the bioreactor are used.

CONSEQUENCES ON FNS / SOCIETY

One has to keep in mind that cultured meat does not appear to offer substantial benefits over poultry meat or eggs, with similar feed conversion efficiency, but higher direct energy requirements. Comparison with the land use savings from reduced consumer waste, including over-consumption, suggests greater benefits could be achieved from alternative dietary transformations considered [1]. Estimations of reducing land use for meat production by cultured meat production range up to 70%. This could mean a shift in land use for other agricultural products or reforestation. What this could mean for the future of farms and farm structures has not been described so far. A transition to cultured meat could exceed the land use changes seen in the past when tractors and automobiles replaced animals for work and transportation, still afforestation or reforestation is not guaranteed.

Additionally, one has to take into account the use of by-products from livestock production, such as feather, leather or bones for gelatine production that would not be possible with cultured meat.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Although considerable progress has been made during recent years, important issues remain to be resolved, including the characterization of social and ethical constraints, the fine-tuning of culture conditions (using alternatives to beef stock as growth medium), and the development of culture media that are cost-effective and free of animal products. Consumer acceptance and confidence in in vitro produced cultured meat might be a significant impediment that hinders the marketing process [2]. According to [3] only 11% of consumers would be willing to buy “cultured meat” if given the choice between this and “plant based” and “normal” beef burgers.

Lack of trust and scepticism if gene engineering is used in this technology from consumers could be overcome by guarantee of safety. Marketing can still influence the acceptance of this technology in either way. RRI could support this with the early involvement of consumers in the innovation process also considering welfare aspects like the environment as well as alternative energy source and socio-economic impacts.

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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

NEW TECHNOLOGIES IN FOOD PRODUCTION

TREND

New or Novel food technologies (NFTs) are scientific and technological developments that enhance the way food is produced or processed, which may or may not result in differentiated – i.e. cheaper or healthier - products for consumers. Novel food technologies are used in all steps of food production from forming, emulgation to extraction, separation, cooking or preservation.

SHORT DESCRIPTION

A variety of new food technologies that are currently used in all steps of food production are leading to faster or safer production processes in order to achieve food products with new properties, longer shelf-lives or lower production costs. Some examples of NFTs are:

- *Forming* Technologies (Nanotechnology, 3D printing)
- *Emulgation* technologies (membrane emulgation, microfluidization, ultrasound emulgation)
- Cutting technologies (using water beam, laser, ultrasound)
- *Separation* technologies (membrane, adsorption technologies)
- *Extraction* methodologies (hypercritical CO_2)
- *Processing/cooking* technologies (super heated steam, microwaves & induced steam, sous-vide, induction heating)
- *Preservation* technologies (IR, UV, Radiowaves, pulsed electric fields, Pascalisation – High pressure treatment, cold plasma)
- Filling technologies (aseptic filling, clean room technology, super cooling)
- Packaging technologies (see separate trend)

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DEVELOPMENT-DYNAMICS AND DRIVERS

Among the key drivers influencing the uptake of novel food technologies (NFT) in food processing are the demand for food safety and prolonged product shelf-life, yet these depend on consumer acceptance. Industry-wide applications of these new processing technologies may be taken up rapidly when they contribute to raising efficiency and security.

The demand for NFTs lies also in possible health claims, that are a strong economic driver opening new markets. These include personalized nutrition or the medicalisation of food. Moreover, the pressure on governments by NGOs to use less fat, salt, sugar may also drive the need for NFTs. Public awareness for higher food safety and for health issues underpinned is by science.

NFTs such as 3-dimensional (3D) printing also allow the design of new organoleptic experiences as the will have an impact e.g. on improving textures.

CONSEQUENCES ON FNS / SOCIETY

NFTs claim to make food

- **cheaper** (by making processing cheaper to compensate for predicted raise in food prices)
- **safer** (for instance, by transferring existing technologies from other fields into the food domain to prevent food poisoning)
- **healthier** (containing less sugar, fat, salt; better bio-availability making it easier for the human body to uptake micronutrients in the system). This may eventually lead to a reduction of food waste.

Despite the claim to improve the availability of more (quantity) and better (quality) food, the socio-political issue of who will benefit is yet to be addressed (**equity** issues).

CHALLENGES – NEEDS FOR R&I STRATEGIES

The public perceive and evaluate both technologies and food in numerous, and sometimes unexpected, ways based on associated meanings that are socially constructed and strongly embedded, i.e. shaped by prior beliefs and expectations.

Responsible research and innovation (RRI) approaches offer multi-stakeholder strategies to better understand the consequences of NFTs, particularly in terms of the health claims. Research is called for regarding the impact of NFTs on nutritional value (e.g. vitamin content). The results will contribute to consumer acceptance.

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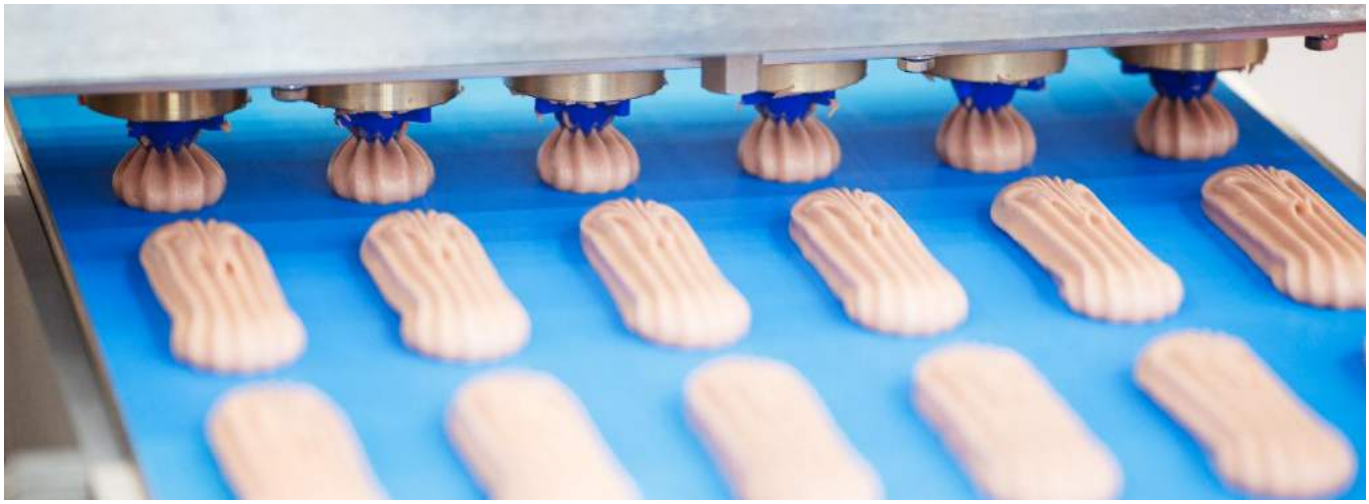
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

HIGH/ULTRA PROCESSED FOOD

CHALLENGE/TREND



A new classification for food categorises food according to the extend of food precessing rather than terms of nutrients. Ultra-processed food and drink products are regarded as convenient, safe, affordable and higly palatable. However, resent studies have linked a higher intake of ultra-processed foods with higher risks in cancer, obesity, hypertension or dyslipidaemia.

SHORT DESCRIPTION

Ultra-processed food and drink products are described as industrial formulations typically with five or more ingredients, substances not commonly in culinary preparations and/or additives to imitate sensory qualities and undergoing industrial processes not common in domestic households, like extrusion or ultra-high-pressure pasteurisation.

Diets in many countries have shifted towards a dramatic increase in consumption of ultra-processed foods, as they are highly convenient, affordable, microbiologically safe and also saving a lot of preparation time. Resent studies on the other side are warning, that ultra-processed foods are often characterised by lower nutritional quality and the presence of additives, substances from migrations out of packaging material or compounds formed during processing. Studies are linking higher incidences in dyslipidaemia, overweight, obesity, hypertension and even cancer with a higher uptake of ultra-processed food.

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DEVELOPMENT-DYNAMICS AND DRIVERS

As part of industrialization the nature, extent and purpose of food processing has been revolutionized. In the last 50 years packed, ready to eat, drink or heat fast & convenient products became increasingly prominent in the food suplies and dietary patterns of high income countris. New production, processing, packaging and distribution technologies have enabled the increase in ultra-processed food. Also lifestyle and changing eating and cooking habits are strong drivers for the promotion of fast, convenient ultra-processed foods.

CONSEQUENCES ON FNS / SOCIETY

Recent studies have associated higher consumption of ultra-processed food with an increased cancer risk, higher obesity, overweight, hypertension and dyslipidaemia. Reasons for this may be that ultra-processed foods oftern have higher content of total fat, saturated fat, added sugar and salt with lower levels of fiber and vitamins. Also authorised, but controversial food additives, such as sodium nitrate or titanium dioxide, are added in food processing. Migration of unwanted substances from packaging material has also been postulated and mentioned as reasons for the negative effects of ultra-processed foods.

On the other side ultra-processed foods enable more convenience and higher food safety for the consumer, benefitting the modern lifestyles and eating habits. Mass production and better distribution of processed foods ensure affordable and highly palatable foods also in remote areas. Higher food safety contributes to lower levels of food borne diseases.

CHALLENGES – NEEDS FOR R&I STRATEGIES

The effects of nutrition on human bodies are only visible after long time periods, thus it is difficult to gain insight on connections of ultra-processed food with non-communicable diseases, such as overweight, obesity or cancer. The results of recent studies should be confirmed by other large scale, population based observational studies in different populations and settings. Further studies are also needed to better understand the relative effect of nutritional composition, food additives, contact materials, and neoformed contaminants in this relation. Rapidly increasing consumption of ultra-processed foods may drive an increasing burden of cancer and other non-communicable diseases. Thus, policy actions targeting product reformulation, taxation, and marketing restrictions on ultra-processed products and promotion of fresh or minimally processed foods may contribute to primary cancer prevention. [1]

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

CLEAN EATING / TRANSPARENT LABELS

TREND

Using "Transparent Labels" the food industry is communicating to the consumers that a product contains a certain ingredient or additive, or whether a product has been produced using "natural" production methods (e.g. organic agriculture or minimally processed food). It is a consumer-driven movement, demanding a return to 'real food' and transparency through authenticity. [1]

SHORT DESCRIPTION

Consumers in industrialized countries are nowadays much more interested in information about the production methods and components of the food products that they eat, than they had been 50 years ago. Some production methods are perceived as less "natural" (i.e. conventional agriculture) while some food components are seen as "unhealthy" and "unfamiliar" (i.e. artificial additives). There is no clear definition on what "clean label" actually includes.

Surveys have shown that "Clean or transparent label products" are associated with natural, organic logos, free from artificial ingredients, other associations were "free from allergens, GMOs", minimally processed", "short & simple ingredients list", or "transparent packaging", but consumers around the world have different associations. The most accurate definition could be foods containing natural, familiar, simple ingredients that are easy to recognize, understand and pronounce, with no artificial ingredients or synthetic chemicals. [1, 2, 3]

Labelling and labels should be comparable, transparent, simple, relying on same/comparable methodologies, accessible to consumers and verifiable online or by digital technologies.

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DEVELOPMENT-DYNAMICS AND DRIVERS

We can find a growing demand for transparency from consumers to allow them to make rational choices about the food they buy. Too much labelling is considered as confusing and misleading. Clean/transparent labels are considered to mark foods containing natural, familiar, simple ingredients that are easy to recognize, understand and pronounce, with no artificial ingredients or synthetic chemicals.

Furthermore, growing pressure comes from society/ NGOs/ governments to encourage and enable sustainable and healthy consumer behaviours and food choices in order to 'move' the food system into more sustainable food production. Green labels are considered to support this pathway to this overall goal.

CONSEQUENCES ON FNS / SOCIETY

There is a potential new market for food industry of consumers that are willing to pay more for fair, sustainable and/or healthy food. Food companies see this trend as an opportunity to develop new products, which are e.g. minimally processed, but still meet the demands from logistics or shelf-life. Research priorities have been identified to meet this demand.

If a holistic, standardised and trustful labelling system would be developed and implemented, more 'power' is given to consumers to influence the food industry towards more sustainable/healthy food products.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Trade-offs and tensions of consumer choices between price and other food aspects and sustainable & healthy foods need to be further investigated and understood. This also includes the research on consumer views, conceptions of and reactions towards labelling sustainability (combining factors such as food spoilage, food quality and food waste), and how to change consumer views toward a positive development. Furthermore, more research is necessary to meet the demand for minimally processed food or food with less additives and the need for longer-shelf life or from logistic.

It is necessary to develop smart labelling of the sustainability of food and diets, which meets the need of the consumers including e.g. computer chips and other IT solutions. Also, standardisation and integration of assessment/labels of sustainable, healthy and fair food products needs to be established.

Research how to balance between regulation and incentives in relation to food labelling and transparency of food products is required.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

NOVEL FOOD

TREND

Novel food has entered the food market in the last two decades. It is based on a number of recent innovations, such as new isolated food ingredients, micro-organisms or novel animal ingredients like insects or new production processes. Despite much interest in Western population due to their nutritional and environmental advantages, novel food products also have very high product failure rates.

SHORT DESCRIPTION

The European Union Regulation defines "novel food" as food or food ingredients that were not used for human consumption to a significant degree within the EU before 15 May 1997 (EU Regulation, 1997). One focus of novel foods is the intent to establish new protein sources, thus a focus lies on insect-based food, a trend with opposing dynamics.

Novel foods as such go beyond the mere use of insects as new source for protein and other components, but include: foods and food ingredients with a new or intentionally modified primary molecular structure (e.g. fat substitutes); foods and food ingredients consisting of or isolated from microorganisms (e.g. cellular agriculture [5]), fungi or algae; as well as from plants or from animals. Furthermore, foods and food ingredients to which a production process not currently used has been applied, where that process gives rise to significant changes in the composition or structure of the foods or food ingredients which affect their nutritional value, metabolism or level of undesirable substances.

Applications under the Novel Food Regulation of the EU range from the use of Chia seeds, Stevia or Noni to genetically modified plants, use of new sugars like trehalose or rooster comb extract to processing technologies like high pressure food processing.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

For years now, the food industry has been facing an increasingly competitive and more globalised market. At the same time, consumers have been expressing more stringent demands and greater concern for quality and health benefits in the products they purchase and consume. As a result, issues such as market saturation and changing consumer preferences are forcing food producers and processors to develop new products in order to meet consumer needs and demands and position themselves competitively in the marketplace [3].

New innovations, globalisations and technical developments have led to considerable increase in the number of new foods entering the market over the last decade. People have become more open and keen to experiment with new ingredients and (up to then) unknown or unusual ingredients and foods. New experimental food be regarded as a lifestyle trend in itself for some consumer groups. On the other side food neophobia plays a huge role and is coined as the tendency to avoid unfamiliar foods. For the acceptance of novel foods such as insects socio-demographic variables play a role: age, gender and place of residence [1].

Factors such as introducing technologies not previously used for food production, the demand for new sources of nutrients or ingredients (e.g. protein sources, minerals or vitamins) and the increase in consideration of environmental issues are driving forces behind the development of novel foods, apart from the mere wish to increase profit of companies.

CONSEQUENCES ON FNS / SOCIETY

The development of novel foods has also led to the development of new business ideas especially in cities, small start-ups specializing in a (niche) product / production. Some foods, that may be considered as “novel” according to the EU Regulation are considered as “traditional” in other countries and are introduced through globalization and migration.

For local farmers and producers the introduction of novel foods or ingredients opens a door to new sources of income. From an ecological point of view the production of insects as protein source is considered more sustainable for the environment than breeding cattle. New production technologies may also contribute positively to environmental life cycle assessment and ecological foot-print.

Consumers non-acceptance of novel foods or processing methods can be positively influenced by a positive contribution to the encvironment as well as by open and factual information, clear statements about the safety and benefit of these technologies, and visual exposure of products [2, 3, 4].

CHALLENGES – NEEDS FOR R&I STRATEGIES

Critical success factor for consumer acceptance as for all food products is the optimization of sensory quality. Food safety, hygiene and micobiological criteria as well as risk assessment for allergies are also focus of concern for novel food products. Nevertheless, sensory alone is not a guarantee to success on its own, but various extrinsic factors have to be taken into account. These extrinsic factors include contextual, cognitive, social, cultural and attitudinal variables related to both the product and the prospective consumer of the product. The arrival of new products appears to create a climate of ambivalence or insecurity, in which some innovations meet with opposition and suspicion, while others easily become part of the daily routine [3]. In the case of novel foods concerns about the nature of the food and/or the nature of the processing technologies that have been used to treat the food become paramount considerations for the consumer faced with choice and purchase decisions. [4] Future research on novel food and processing or preservation techniques should move away from simple assessment of consumer concerns to integration and information of consumers, as factual information and clear statements about safety and benefits of new technologies or ingredients increase consumer liking upon initial trial [4].

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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

NATURAL PRESERVATIVES & MILDER PROCESSING METHODS

CHALLENGE/TREND

Preservation of food is essential for prolonging shelf-life and ensuring food safety. Modern processing technologies aim at gentle preservation, a combination of preservative factors and their interaction and the use of natural rather than chemically syntetized preservatives. Reason behind it is the retention of food quality with high nutritional values for health.

SHORT DESCRIPTION

Preservation of food has been used since ancient times in order to keep up the nutritional values for health for a long time and make food available throughout the year. Preservation methods restrain the development of microorganisms and food spoilage, while maintaining taste, texture, flavour and quality. Many food products are sensitive to temperature or vulnerable to chemical, physical or microbiological changes.

Milder processing technologies aim at gentle preservation, while possibly also encountering environmental preservation, reducing the use of water and solvents, waste water, fossile energy use or generation of harmfull substances [1].

Another issue in this trend description is the fact that synthetic preservatives are replaced with natural ones, such as salt or vinegar. Combination of preservation methods, the socalled hurdle technology, have become prevalent as principles of major preservative factors for foods (e.g. temperature, acidity, water activity, competitive flora), and their interactions, became better known [2].

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DEVELOPMENT-DYNAMICS AND DRIVERS

Minimal-processing methods all involve processing procedures that change the inherent fresh-like quality attributes of the food as little as possible (minimally) but at the same time endow the food products with a shelf life sufficient for its transport from the processing plant to the consumers [4]. Development of new preservation technologies, e.g. ultra-high pressure pasteurisation, and the improvement of conventional processes, e.g. milder thermal processing, are aiming to retain the food quality in healthy products.

The hurdle technology combines mild preservation methods for gentle, but effective preservation of foods while ensuring food safety, e.g. mild heating and cold storage in combination with packaging in low oxygen atmosphere.

Another driver behind this trend is the consumer perception of “bad, toxic or unhealthy” synthetic preservatives. Natural preservatives are perceived much safer for health and environment. They are easy to obtain since the sources are from plants, animals or microbes origin. Synthetic preservatives, such as sulphites, benzoates or sorbates are replaced with natural ones, like salt, vinegar, sugar or honey, or extracts from plants, animals or microorganisms.

More environmentally friendly processing methodsfulfill the increasing demand from consumers for “greener” products.

CONSEQUENCES ON FNS / SOCIETY

Less severe preservation procedures are being developed that make use of preservative factors in combinations to deliver: (a) less damage to product quality (hurdle technologies); (b) new methods of heating that are better controlled and therefore deliver milder heat to products; (c) cook-chill and other combinations that deliver longer high quality shelf lives; (d) modified atmosphere packaging to retain quality longer; (e) use of antimicrobial systems that are more natural [6] and (f) use of “natural preservatives” derived from plants, animals or microorganisms. Consumer studies have shown that consumers have recently become more informed about food additives and always tend to choose the additives of natural origin than their synthetic analogues [3].

New food processing technologies also take environmental and ecological aspects into account in order to fulfil their role in promoting sustainable food industry. The techniques are not new, but are now encountered in view of water and energy consumption, carbon footprint or processing time [5].

CHALLENGES – NEEDS FOR R&I STRATEGIES

Surprisingly there is no definition of natural preservatives, antioxidants, colors or sweeteners. Only natural flavorings have legislation both in the EU and the USA, and this is then transposed to the other classes of additives, leading to wrong interpretations and the confusion of what is natural or synthetic. There is a growing need for transparent legislation regarding the natural additives, for they are of growing interest in developed countries [3].

The food industry is a very competitive environment and to survive they have to use optimized processes and to reduce the carbon food print. More sustainable food processing methods meet the demand of the final consumer in terms of “greener” product, an education work will have to be done in order to explain what the benefits are for the final consumer [5].

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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

ALTERNATIVE PROTEIN SOURCES

CHALLENGE/TREND

Consumption of sufficient dietary protein is fundamental to muscle mass maintenance and overall health. However, the production of sufficient amounts of conventional animal-based protein to meet future global food demands represents a challenge. Edible insects, cultured meat and microalgae have recently been proposed as alternative protein sources that may be produced in a more sustainable way and may contribute to ensuring global food security.

SHORT DESCRIPTION

With projected increases in global population numbers, there is also an increasing demand for animal-based, protein-dense foods such as meat, eggs, and milk products. This poses major concerns for the sustaina-ble production of safe and nutritious food. The world-wide production of agricultural commodities such as maize, rice, wheat, and soy, which represent key sources of plant-based dietary protein, may also need to increase to meet global demands. Consequently, to address these needs alternative sustainable sources of valuable dietary proteins are sought for.

Edible insects could play an important role in addressing the impending protein supply crisis. Overall, insects contain sufficient levels of protein, fats and micronutrients to contribute to improvements in global health and food security, both via direct consumption and indirect use in feeds.

In addition, protein-rich microalagae and lab-cultured meat could also provide relevant protein sources in the near future.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

Protein is one of the fundamental building blocks of the human diet, and powerful factors are driving the development of novel sources. It is estimated that global protein consumption could reach 944 MMT by 2054, around the time that many sources predict a population of 9 billion (473 MMT in the mid-2000s). As demand for protein grows more rapidly than conventional meat sources can supply, the food industry will have to respond by supplying non-meat-based proteins. It is estimated a possible 9% annual growth for the alternative protein sources over the coming 40 years [1].

In the next 10 years, first generation protein i.e. soy-derived, will continue to dominate. By 2024, it is predicted that the second-generation plant protein from sources such as pea, rice, flax, canola, and lupin will share 9% of this market. The growth rate in this decade will be almost three times that of first-generation soy protein, encouraged by consumer concerns over the potential negative health impacts from over-consumption of soy. Third-generation plant proteins – like moringa, quinoa or chia – will represent 4% of the alternative proteins market by 2024, while sales of insects and algae as protein sources will also increase up to 2% each of the alternative protein market [1].

Entomophagy, the consumption of insects, shows great potential as an environemtally friendly and sustainable food choice in the western world, if consumers can be motivated to substitute meats with insects. Feasible strategies could include the stressing of the low environmental impact of insect products compared to meat, a positive sensory experience when consuming insects, availability and convenient pricing. [2] To date, more than 2000 species of insects have been reported to be used as food by humans.

Cultured meat (see separate trend description), is produced by culturing animal stem cells in a medium that contains nutrients and energy sources required for the division and differentiation of the cells into muscle cells. For large-scale production, the culture technique needs to become more efficient than current standard techniques.

Imitation meat or meat analogues attempt to mimic specific types of meat, including the aesthetic qualities (e.g. texture, flavour and appearance) and the nutrient qualities, e.g. soy based products, such as tofu or tempeh.

The high protein level of various **microalgal species** make them an ideal alternative protein source. *Spirulina platensis* is one of the richest protein sources of microbial origin, having similar protein levels to meat and soybeans. [3]

CONSEQUENCES ON FNS / SOCIETY

Whether a global adoption of entomophagy and the consumption of other alternative protein sources could help alleviate growing pressure on the environment from food production, and reduce malnutrition in both developed and developing countries, is a topic of extensive debate. A transition from animal-based to plant-based proteins is considered to be beneficial for biodiversity, land use, water use, climate, human health and animal welfare. Imitation meat and insects seem to have the highest land use efficiency. In addition, insects produce lower greenhouse gas emissions, while requiring less water and land compared with traditional animal husbandry. Therefore, eating insects can also contributes positively to nutritional security. In addition, export and import of insects for food plays a strong economic role throughout South-East Asia. [4] However, commercialisation of in vitro meat and edible insects will largely depend on the acceptance by consumers. Another major concern for all novel foods, and particularly those containing proteins, is their potential to cause food allergy.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Food companies are expected to develop novel formulations to incorporate alternative proteins into existing products. Seed companies should work on breeding programs for the protein-rich crops now to capitalize on the expected shifts in farmer demands. Ingredient producers should focus on extraction technologies for these alternative sources to speed the market growth of these proteins. [1] Concerning edible insects, future research should focus on the scaling up of insect production to commercial levels, 'anti-nutrient' properties, concerns around food safety related to storage and allergic reactions, consumer acceptability and ambiguous or non-existent regulation.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

FUNCTIONAL FOODS INCL. PRE- AND PROBIOTICS

TREND

Functional foods (including pro- and prebiotics) affect beneficially physiological target functions in the human body, beyond adequate nutritional effects, in a way relevant to an improved state of health and well-being and/or reduction of risk of disease. These health claims influence purchase decisions among consumers and drive the demand for the functional foods as they promote better health, increase longevity and prevent the onset of chronic diseases.

SHORT DESCRIPTION

Since dietary components can play various beneficial roles that go beyond nutrition, the functional foods market is rapidly expanding.

Functional foods are foodstuffs that are consumed as part of the normal diet and that contain biologically active components which offer the potential of enhanced health or reduced risk of disease. Examples of functional foods include foods that contain specific minerals, vitamins, omega-3 fatty acids, plant sterols or dietary fibre, foods with added biologically active substances such as phytochemicals or other antioxidants and probiotics that have live beneficial (bacterial cultures).

The consumption of live bacteria (probiotics), e.g. lactobacillus and bifidobacteria species, and ingestible food constituents such as prebiotics are the most well characterized dietary bioactive compounds and have been demonstrated to beneficially impact the gut health and the overall well-being of humans by modulating the intestinal microflora. The gut microbiota is the assembly of microorganisms living in our intestine and their genomes are known as the microbiome. The correct composition and functionality of this microbiome is essential for maintaining a “healthy status.”

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DEVELOPMENT-DYNAMICS AND DRIVERS

The concept of "functional foods" was introduced in the mid-1980s in Japan and refers to processed foods that are not only nutritious but also aim to target health and well-being by containing biologically active components with a potential for enhancing health or reduce the risk of disease. The EU project "Functional Food Science in Europe" (FUFOSE) provided a working definition: "Foods can be regarded as functional if they can be satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way relevant to an improved state of health and well-being and/or reduction of risk of disease. Functional foods must remain foods and they must achieve their effects in amounts normally consumed in a diet." [1] Examples of functional foods include foods that are fortified with specific minerals, vitamins (e.g. cereals), flavonoids, fatty acids (omaga-3 in cheese) or dietary fibre, and foods with added biologically active substances such as phytochemicals or other antioxidants and probiotics (in yogurt) that have live beneficial (bacterial cultures). Probiotics and prebiotics (ingestible food constituents) are the most well characterized dietary bioactive compounds. The lactobacillus and bifidobacteria species are the predominant probiotics up to now. Health benefits attributed to probiotics comprise: modulation of gut microbiota (the assembly of microorganisms living in the intestines), immune response enhancement, improved gastrointestinal health, and protection against infections such as acute gastroenteritis illness and inflammatory bowel disease. [3] The appropriate composition and functionality of the microbiome (genomes of the gut microbiota) is essential for maintaining a "healthy status." Functional foods are not pills or capsules, but can be consumed as part of the usual diet.

Increased life expectancy, resulting in an ageing population, and growing health concerns among consumers in developed countries are met with the health claims (e.g. better health, increased longevity and prevention of the onset of chronic diseases) of functional foods, which present a convenient and inexpensive solution to chronic health problems. These health claims are a key factor for purchase decisions among health-conscious consumers and drive the demand for these new foods. With a fast-emerging middle class and more disposable income, the worldwide potential for functional foods/beverages is steadily increasing. These trends have attracted commercial attention and prompted the food industry to increase research and development of these new foods and thereby led to a rapidly expanding functional food market in many countries. [2] However, there are worldwide uncertainties with respect to existing regulations.

CONSEQUENCES ON FNS / SOCIETY

Cardiovascular disease (CVD) is now the leading cause of death globally. Lifestyle factors, including nutrition, play an important role in the etiology and treatment of CVD. Functional foods based on their basic nutritional functions can decrease the risk of many chronic diseases and have some physiological benefits.

Currently, dairy products seem to have the biggest share in the functional food market, followed by beverages and cereals. The general success of fortified beverages indicates that drinks are an accepted vehicle by consumers. In terms of ingredients, probiotic bacteria cultures are the dominant bioactive ingredient, which can be explained by the dominance of dairy products.

However, the lack of a consistent definition between countries has led to unregulated publishing of health claims in some, limiting of functional food production in others, and an overall mistrust or unclear sense of what "functional food" is among the public. In Europe, there is no specific regulatory framework for functional foods, although European labelling legislation does not allow attributing the property of preventing, treating or curing a human disease or referring to such properties in any food product.

CHALLENGES – NEEDS FOR R&I STRATEGIES

There is a need for a consistent definition of functional foods between countries globally. To be able to build a strong and acceptable scientific basis for functional food claims, it is essential to demonstrate the bio-efficacy of functional food components in vivo and not only by performing in vitro tests, even though this is a complex and costly task. For most products, the optimal levels of nutrients and other physiologically active components in functional foods have yet to be determined in humans. The safety evaluation of dietary functional components must take into account potential adverse effects of low and too high intake. In addition, there is also a need to identify new functional food ingredients and to gain consumer acceptance of such products.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

4. CONSUMER TRENDS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

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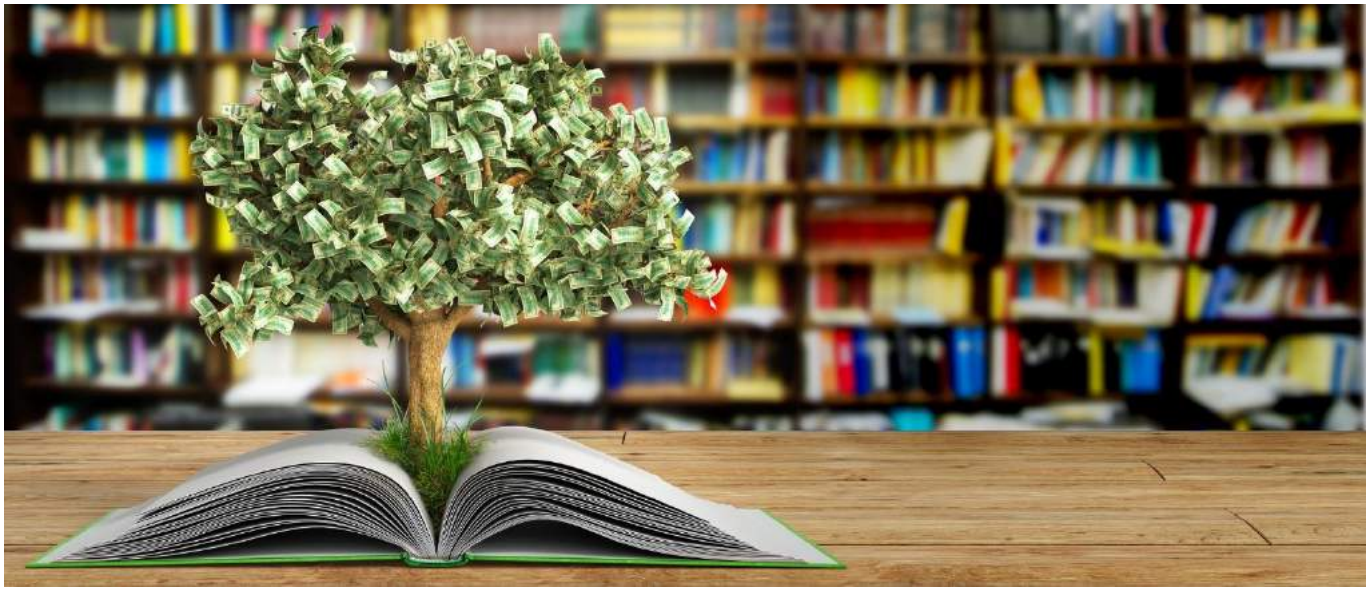
HEALTH AND FOOD CONCIOUSNESS

TREND



Consumers increasingly start to understand that everything they eat has an effect on their health and wellbeing. This understanding enables more deliberate food choices and leads to empowered counsumers.

SHORT DESCRIPTION

The Center for Food Literacy defines food literacy as “understanding the impact of your food choices on your health, the environment, and our economy” [1].

Increasing food literacy brings consumers to understand what effects food has on their health and based upon that make deliberate choices: Knowledge about flavour enhancers in industrialised food, the calories in food especially made for children, trans fats, etc. impact on consumer choice. Increasing food literacy brings people to make choices for their health and wellbeing leading to higher consciousness on health, food an the relation between both.

Food literacy is also a challenge as it is a form of empowerment and usually poorly distributed among populations with lower education levels.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Health and food literate consumption is driven by highly educated consumers who are alert and aware of the health effects of nutrition.

In general, there is more information on food available though the internet as well as through branding and labelling. Food safety scandals result in more information about the food and nutritions system through commercial media and hence have an educational effect as well. Vegetable patches and school gardens and other initiatives in schools try to educate on food and nutrition from a young age. The increase of life-style and diet-related diseases leads to higher awareness in growing parts of the population.

Social media and internet are influencers, food and fashion hypes are more likely to affect people.

All these mechanisms result in a more detailed perception of the impacts of food on health and wellbeing.

CONSEQUENCES ON FNS / SOCIETY

This more enhanced understanding of the impacts of food on health and wellbeing should lead to healthier diets and decrease NCDs.The time horizon of this depends on the strength of the trend.

More demanding consumers require higher quality products at higher prices, which results in health and wellbeing being socially determined.

There is an important role for independent NGOs in informing about health threats and effects of ingredients on health. NGOs are often translators from scientific studies and hence are important actors in transdisciplinary processes.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Many people do know that food influences their health, but not what and how. There are education needs, schools increasingly take a role. Are there other roles?

There is a chasm between knowing and doing. An increased understanding of why people choose pieces of food can facilitate more healthy choices.

Studies and results have to be made widely availbale, not only to an interested highly educated public, e.g. chemical migration of plastics into packaged food, fertilizers in certain foods, transfats, antibiotics in bees and hence honey etc.

Media are a filter in the spread of information. NGOs also have a tendency to promote some topics over others (*economics of attention*).

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

RESPONSIBLE CONSUMERS

TREND

Consumers are increasingly interested in the growing history of the food and food miles, i.e. the distance food travels. Its past relates to the way it was grown, produced and transported within the food system. This knowledge empowers consumers to chose responsibly according to their own personal values.

SHORT DESCRIPTION

Responsible consuming is about the impact of food choices on the food system, the environment, and the economy.

Increasing responsibility brings consumers to understand the pathways food goes through the food system and upon that make deliberate choices: the tons of fossil fuels burnt until a salad arrives on their plates, the lives of animals in the food chain, the wage of workers who harvested the cocoa they drink in the morning, the expansion of palm oil cultivation resulting in deforestation, leading to biodiversity loss and problems with greenhouse gas emission due to the conversion of rain forest.

Informed choices by consumers empowers them to support or disempower institutional power frames based on personal values asspciated with responsible purchasing behaviour.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Changes in values and ethical attitudes of consumers are a major driver beind this trend. These will have a major influence on policy-makers, as well as on patterns of consumption in individuals. In turn, food security and the governance of the food system will be affected.

Examples include:

- Issues of national interest and 'food sovereignty'.
- The acceptability of modern technology, in particular (for example, genetic modification, nanotechnology, cloning of livestock, synthetic biology).
- The importance given to particular regulated and highly specified production methods such as 'organic', 'biodynamic', 'conservation grade' or 'sustainably managed'.
- The value placed on animal welfare.
- The relative importance of environmental sustainability and biodiversity protection.
- Issues of equity and fair trade.

CONSEQUENCES ON FNS / SOCIETY

"In Europe, there is a marked change in consumer behaviour towards a higher awareness on food provenance and value-based consumption. The globalisation of food markets brings along the increased attention of consumers towards food quality and safety and "fair" products. At the same time, many consumers prefer local or regional products where these are available.

This complex trend is related to a number of different drivers: shift in ethical and societal values, environmental protection, and consumer communication and information. At the same time, this trend in consumer demand is also very volatile and sensitive to other, sometimes contradicting drivers such as the economic developments and food prices as well as changing lifestyles (e.g. food enjoyment, busier lifestyles)." [3]

CHALLENGES – NEEDS FOR R&I STRATEGIES

Calculating personal footprint could be named as an example to increase consumer awareness:

"As the consequences of mass consumption have become a problematic issue in Western industrialised countries, pioneers of sustainable consumption are questioning the ecological and increasingly also the social "footprint" of their activities. For example, they calculate the CO_2 emissions or water consumption involved in manufacturing their clothing, which would influence their "ecological footprint". The "social footprint" is determined in a similar way, for example by considering the average labour time worked per item of clothing in conditions that violate human rights. In each case, the figures are calculated by analysing process chains across the product lifecycle. Free online tools are now available for both calculations, which work out the footprint based on the user's data. Aware consumption as a result of knowing one's personal footprint addresses needs such as a cleaner environment, meaningfulness, social commitment and health."

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

SPECIAL DIETS LIKE VEGETARIAN, VEGAN OR LOW CARB

TREND

Special diets like Paleo, Detox, Slow carb etc are on the rise world-wide. Among these vegetarian and vegan diets seem to be the most widespread and persisting. Reasons for this are an increased awareness of the positive effects of food on health and well being, changing values towards animals, growing consumer interest in ready-to-eat-food, and growing demand for food with higher safety standards.

SHORT DESCRIPTION

The number of people who choose special diets for themselves for ethical and health reasons is increasing as well as the number of diets, like Paleo, Detox, Keto, to name just a few.

The most popular among these are vegetarian and vegan diets. Research indicates that the number of vegans worldwide is on the rise, especially in more affluent countries [1]. Increasing food literacy, changing values (changing human-animal relations), and life style back up this trend.

Besides an increasing consumption of fruits and vegetables in general, there is an increasing tendency to more convenient fruits and vegetables as well. An important sub-market of the whole fruits and vegetables market is the market of fresh-cut products, i.e. fruits and vegetables ready for easy consumption instead of tedious processing.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

The choice and preference for special diets is best documented for for the vegetarian/vegan food consumers, compared to other diets. There appears to exist different trajectories for becoming vegetarian/vegan, first due to health, and second, due to ethical reasons. Once vegetarian, ethical reasons are most likely to cause a transition to becoming vegan. Those choosing a vegetarian diet for moral reasons report greater disgust with meat and a more intense emotional reaction to meat consumption compared to those who became vegetarian for health reasons [1].

Environmental concerns are part of ethical reasons and do also play a considerable role in more people turning to plant-based diets. One example is livestock farming which has impacts on greenhouse gas emissions from human-related activities [2].

More new and interesting fruits and vegetables are available which also sparks interest in these kinds of food. This is related to globalised diets and the increased availability of foods from around the world [3].

CONSEQUENCES ON FNS / SOCIETY

Whereas per capita meat demand in developing countries is likely to grow substantially, consumption of meat and meat products is expected to be steadily decreasing in developed countries. Still, it seems unclear whether the latter trend is actually offset by a gap between consumer attitudes and purchase behaviour.

However, there are still open questions to tackle:

- Transport issues: the widespread availability of different fruits and vegetable poses challenges to transport and has environmental consequences. Societies relying on plant-based diets to large extents do expect variety in the offerings.
- Time management in modern societies and the need to purchase fresh/local foods calls for new options in retail

Long term effects of different diets on human health need to be investigated, numerous studies have shown the connection between diets and non-communicable deaseses.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Questions that need to be answered regarding special plant based diets can be:

- Can enough (organic) fruits and vegetables with enough nutrients be grown?
- Packaging issues for cut products (chemical migration pf plastic packaging)? There seems a growing evidence that many single-use food contact materials, including plastics, may pose health risks to consumers due to chemical migration [4].
- How great is the content loss of vitamins and nutrients in fruits and vegetables today?
- Modern farming and its impacts on fruits and vegetables in terms of chemicals, fertilizers, antibiotics etc.
- How healthy is salad with dressing? (example Fast food chain)
- Impacts of plant-based diets on health (BMI, types of cancers, other diseases. Healthy for children?

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DESTABILIZED CONSUMER TRUST

CHALLENGE/TREND

Public attention to food safety and food fraud is increasing: *Escherichia coli* outbreaks, Fipronil eggs contamination, but also the horsemeat scandal have shaken consumer trust in food in the recent past. Some are actual contaminations and cause foodborne illnesses, others do not meet consumer ethics. Intentional adulteration of foods is getting more public attention and leading to mistrust of consumers.

SHORT DESCRIPTION

Food is an area where consumer trust and confidence is crucial. Disruptions caused by scandals and crises are costly to industry, brand damaging and far reaching.

Awareness of food safety hazards, and reduced confidence in the ability of current food supply chains to adequately cope with food safety risks impact on consumer attitudes and choices.

However, building trust in food, and hence in food supply chains is a complex issue with interdependencies between business strategies, public health concerns, government regulations, consumer demand and social media.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Food safety can be seen as consumers' concern of 1) residues in food resulting from chemical sprays, fertilizers, artificial additives and preservatives. This is often linked to farming methods [1]. And 2) food safety is related to microbiological safety and animal disease-related safety.

Food scandals negatively impact on consumers' trust in the safety of agri-food systems. These large-scale fears have tended to arise after food-related scandals from contamination of food chains at the primary level, and have ignited consumers' concerns over farming methods and technologies. Cases of food fraud, that have been made public, increase consumer awareness to food safety [5, 6]. Furthermore, consumers' concerns have in part been aggravated by the initial mismanagement of some of those crises. This in turn tends to unsettle trust in authorities in general.

As a basic mechanism, one of the main reasons of the changes in consumers' demand is the fact that people have more information every day about all of these different knowledge areas. There is a link to, on the one hand, helath and food literacy, and on the other hand, social media. Consumer issues become more complex as every person can share their views on food safety and quality via social media through words, pictures and videos.

CONSEQUENCES ON FNS / SOCIETY

One of the main consequences for FNS and society is the fast diffusion of organic and not necessarily, but also local produce. In general, consumers seem to believe that organically grown produce poses fewer risks than conventional food products, but more and more reported cases of food fraud in organic claims also undermine consumer trust in the food system. Specifically, lower pesticide-related mortality risks are associated with the consumption and production of organically grown produce.

At the same time this leads to mistrusting new food technologies such as GMO and irradiation. The factors that influence consumers' acceptance of food innovations are risk-benefit perceptions, socio-demographic attributes and knowledge and information, as well as the level of trust in the source of that information [2, 3, 4].

CHALLENGES – NEEDS FOR R&I STRATEGIES

Technical and scientific innovation may have essential impacts on food safety and its management. However, whereas some forms of innovation will be quite easily accepted by consumers like more sensitive detection methods for investigating and discovering new food safety hazards, others may have difficulties like new and emerging technologies in food production, post-harvest treatment, and processing. New technologies like nanotechnologies for example are expected to play a big role in addressing food safety challenges but at the same time may also bring potential new risks to both human and environmental health.

Regarding food fraud EUROPOL has already started the OPSON project years ago, and still points to tne necessity of strong collaboration not only of police forces, but of all sections within the food system, as food fraud includes aspects from food insecurity, agricultural labour, livestock welfare, genetically modified foods, food sustainability, food waste, food policy, or food democracy [5, 6].

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

FAST AND CONVENIENT FOOD

TREND

In general, there is a trend towards fast and convenient food, which is often – but not necessarily – unhealthy and leads to high amounts of waste. It is accompanied by personal lifestyles that do not allow much time for the preparation and consumption of food.

SHORT DESCRIPTION

Convenience food choice is positively associated with the lifestyle (social events breakdown of mealtimes, eating alone, novelty) and time constraints, but negatively related to cooking ability and importance of freshness into food choice. There are different convenience categories like take-away meals, ready meals, and pub-restaurant meals [1].

According to [2] convenience foods are often regarded as among the least healthy and sustainable of dietary options because of their low nutritional value, wasteful packaging and heavy reliance on imported ingredients. Nevertheless, healthy convenient options are spreading in supermarkets. The market for fresh-cut products since its beginning in the early 1980s has been experiencing double-digit growth; packaged salad seems a major attractor representing around 50 per cent of the fresh-cut market volume. Limited spare time, social environment and eating out are the causal factors behind this trend.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

The main drivers of this trend relate to the changing society, mainly in developed countries. The change in lifestyle is driven by the increased share of working women and the consequent time constraints on cooking activities. Also, the increased share of single households brings to a demand for portioned and convenient packaged food, which business are cleverly exploiting, increasing the offer of such products.

One driver here has traditionally been the commercial marketing to children of food and drink with unhealthy (sugary) content. However, in the recent past there has also been commitment from soft drink producers to reduce advertising (see 100% no advertising to under 12's in print, online or social media and 99% no advertising on TV [3].

Furthermore, the traditional and social value attached to cooking for family and friends is being gradually replaced by eating out and/or delivery of food at home. Eating out at a restaurant or take away has a social value as it gathers people together for the mealtime, this is becoming more frequent at all age groups. Accordingly, the offer of restaurants is vast and one can easily find a restaurant for any budget.

On the other hand, cheap food products and take-away are often unhealthy and this kind of food has recently also reached developing countries; if coupled with low awareness and education about healthy diets, this could be a severe threat to the health of these populations.

CONSEQUENCES ON FNS / SOCIETY

This trend has several consequences:

- increase in obesity and non-communicable diseases
- increased amount of waste
- at a social level, risks and consequences involves the lack of cooking ability and the detachment from what people eat: not preparing your own meal leads to a scarce knowledge about the ingredients used and ways of cooking. It has the side effect of reducing control over your own diet
- Societal changes involving places of aggregation, the meal eaten out becomes a moment and place of aggregation with others, with greater importance than a home-cooked meal.

CHALLENGES – NEEDS FOR R&I STRATEGIES

One big challenge concerns the availability of healthy and convenient options at lower prices, coupled with efficient promotion campaigns on healthier options.

Improve and re-think the waste management along the food chain and for consumers of convenient food, which tipically involve a great amount of wasteful packaging and food. Research and innovation regarding sustainable packaging is needed.

Furthermore, food with reduced or limited fat/sugar/salt content could be an option for improving diets.

EXAMPLE REFERENCES

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[2] Jackson, P., & Viehoff, V. (2016). Reframing convenience food. Appetite, 98, 1–11.

[3] https://www.eatandlivewell.eu/responsible-marketing-and-advertising/no-advertising-to-children-under-12/, last accessed June 20th, 2018)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

LOW PRICES, HIGH CALORIES

TREND

Peoples' dietary styles are influenced by their living conditions and the socio-cultural environment. People with less money, lower educational level, insecure working conditions and poor living conditions are more likely to choose low price food with high fat and sugar contents which are seen as major cause of the high prevalence of non-communicable diseases.

SHORT DESCRIPTION

Although the overall dietary patterns of low- and high-income individuals tend to be similar, there are certain aspects of the low-income diet that are less healthy. In general, individuals on low incomes are less likely to consume wholemeal bread and vegetables, but are more likely to consume fat spreads and oils, non-diet soft drinks, pizza, processed meats and table sugar [1].

Inequalities in nutritional and economic status translate into inequalities in obesity beween socio-demographic segments. In higher-income countries, greater obesity rates occur in rural areas and among the poor, the opposite of what is seen in lower-income countries.

New access to technologies (e.g., cheap edible oils, "empty calories food", modern supermarkets, and food distribution and marketing) and free trade are changing diets in low- and middle-income countries, in which obesity prevalence appears to be rising [2].

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

What, when, where and how much people eat is influenced by a complex mix of factors at societal, community and individual levels. These influences operate both directly through the food system and indirectly through political, economic, social and cultural pathways that cause social stratification and influence the quality of conditions in which people live their lives. These factors are the social determinants of inequities in healthy eating [3].

The main drivers that widen the food gap among different segments of population and between developed and developing countries are listed below:

- Low prices of unhealthy products
- Scarce education and awareness on healthy diets
- New kind of food available in developing countries, which is cheap and high in fat content, and represents the “status symbol of western food”, which made it highly attractive.
- Increase in animal-source food intake
- Technological changes and trade regulations
- Increased access to cheaper processed, high-fat, added-sugar, and salt-laden foods in both developed and developing countries

CONSEQUENCES ON FNS / SOCIETY

The main consequence of this trend is the increase in obesity and other non-communicable diseases rates, together with a problem of micro-nutritional deficiencies.

CHALLENGES – NEEDS FOR R&I STRATEGIES

To address inequities in healthy eating, policy and action must tackle the systemic problems that generate poor nutrition, and reflect on how our food and social systems are making people sick [3]. Strategies must include aspects in a holistic approach, from health to education, integrating the physical environment or Individual health-related behaviors.

Some examples for strategies can be

- Promotion and education strategies about healthy eating, especially addressed to lower-income population segments and people living in rural areas.
- Reduced prices for healthier options.
- Protection and responsible trade and marketing in developing countries.
- Food composition regulations eg. on salt/fat/sugar content.
- Social participation as community-based programs

EXAMPLE REFERENCES

[1] Tiffin, R., & Salois, M. (2012). Inequalities in diet and nutrition. *Proceedings of the Nutrition Society*, 71(1), 105-111.

[2] Popkin, B. M., Adair, L. S., & Ng, S. W. (2012). Global nutrition transition and the pandemic of obesity in developing countries. *Nutrition reviews*, 70(1), 3-21.

[3] Friel, S., Hattersley, L., Ford, L., & O'Rourke, K. (2015). Addressing inequities in healthy eating. *Health promotion international*, 30(suppl_2), 77-88.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

"FREE-FROM" PRODUCTS

TREND

"Free-from" products (which include a range of non-GMO, gluten free, lactose free, fat free, sugar free, histamin free food items) are on the rise. More consumers are interested in self-managing ingredients to control for food intolerances, or to follow specific dietary styles.

SHORT DESCRIPTION

Selective food avoidance (= special dietary requirements) by affluent health conscious consumers who want to self-manage ingredients to control for allergic episodes gives impetus to supply a growing range of "free-from" products. Such products have become fashionable and, in some cases, associated by consumers with weight control or other personal values.

They include non-GMO, gluten free, lactose free, fat free, sugar free, histamin free food. Demand is driven mainly by food hypersensitivities and allergies.

While only around 5 per cent of the population actually need to avoid certain ingredients and food groups on medical grounds, far more join the trend by buying at least one product from the free-from category. A fashion for "clean eating", diets like paleo, vegan and other have driven the supply of specially manufactured products and encouraged supermarkets as well as specialist stores to offer them [1, 2].

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

The public perceives and evaluates both foods and technologies in numerous, and sometimes unexpected, ways based on associated meanings that are socially constructed and strongly embedded, i.e. shaped by prior beliefs and expectations.

Drivers of this trend refer not only to food safety and health concerns, but also to environmental and animal welfare issues.

Other drivers may relate to fashion and a general incorrect association with weight control and free-from products.

CONSEQUENCES ON FNS / SOCIETY

The increased availability of free-from products will guarantee allergic and hypersensitive people a healthy and easy life, contributing to health improvement.

Also, this trend might improve people's consciousness about diet and ingredients in the processed food bought.

On the other hand, eating free-from products for a long time if not necessary might lead to malnutrition problems, for example following a gluten-free diet in the absence of celiac disease may lead to minerals, vitamins and fiber deficiencies.

CHALLENGES – NEEDS FOR R&I STRATEGIES

There are needs for research on the long-term effects of free-from diets on the health of people who do not suffer from food allergies or intolerances (e.g. [1]).

For truly intolerant people information campaigns about free-from foods available can enhance living standards and food safety.

Innovation on processing methods could widen the range of free-from products available while at the same time lowering selling prices.

EXAMPLE REFERENCES

[1] Lebwohl, B., Cao, Y., Zong, G., Hu, F. B., Green, P. H., Neugut, A. I., & Willett, W. C. (2017). Long term gluten consumption in adults without celiac disease and risk of coronary heart disease: prospective cohort study. *bmj*, 357, j1892.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

SMART PERSONALIZED FOOD

TREND

In smart personalized nutrition customers are part of the production process and co-create their own food. Biomarkers and sensor technologies allow a range of new features to technically support the co-creation processes

SHORT DESCRIPTION

Smart personalized nutrition enables decisions for more responsible and sustainable food choices, possibly reducing food waste and fostering innovation. Personalization aims at making customers part of the production process as “co-creators”, “co-designers” or “prosumers”, allowing them to affect or personalize the integral design or configuration of their intended purchase or choice.

Smartness as a feature in food may include biomarkers that report on the health status. Smart personal nutrition offerings need to account for likes and dislikes, ethical, cultural, religious and social constraints, food allergies and intolerances, phenotypic data (e.g. gender, age, body height and mass) and physical activity levels.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

The basis for a trend like smart personalized nutrition amongst others are movements like the “quantified self” that promote “self-knowledge through numbers”. Millions of people use fitness bracelets, smart watches and smartphones to count their steps, calculate their calorie consumption, and monitor their sleep. The technologies are currently still evolving and widely dispersed.

There is a vast interest in “gadgets”, its combining with personalized information in nutrition makes food interesting. Higher value is attached to food in general, smartness and personalization of food information apparently results in increased trust in advices and allows consumers to configure actively what they eat.

NCDs and technological opportunities are likely to accelerate the trend as there are huge gains in tackling daily challenges of diseases like diabetes, or cardiovascular diseases. However, links to public health care systems are often difficult to establish.

CONSEQUENCES ON FNS / SOCIETY

On the one hand there are already a multitude of young, dynamic, stylish, cheap, web-based apps available and in use by many. Supply of these occurs through small firms or individual programmers to large extents. There are very short short innovation cycles, demand is difficult to foresee, as it is viral in adoption and in dropout.

On the other hand, it is vital to take a wider systems view in analyzing the diffusion of wearable technologies for self-measurement, a view which situates these within health and social care service systems. The concept of smart technologies is often collapsed into the specific information systems that are constructed to support new health care services; or even into the specific devices that are employed within these information systems, such as wearable sensors to monitor health conditions and/or behaviour patterns. A wider approach takes into account the need to design complex architectures relating together people (recipients of care, care-givers, and others), organisational structures and processes (that determine divisions of labour and responsibilities, flow of resources, etc.) and technologies (especially the information technologies, but also other health and social care-related devices and software).

CHALLENGES – NEEDS FOR R&I STRATEGIES

What is vital for R&I in this area is an evidence base of how and where the use of smart technologies exactly adds value to the nutrition and health status of individuals.

How health care organizations deal with their accumulated digital information (big data) is crucial for the uptake of health ICTs (information and communications technology). Sharing sensitive patient data in a large heterogeneous environment complemented by the use of web-based applications raises a number of privacy and security concerns.

There is concern that smart technologies on the one hand might not be available for everyone and add to differentiation of medical care between social classes. On the other hand through the variety of web-based applications that collect personal data the contrasting concern is that it makes too comprehensive concessions on privacy.

EXAMPLE REFERENCES

[1] SMART PERSONALIZED NUTRITION: QUO VADIS”, authored by Prof. Hannelore Daniel, Technische Universitat Munchen/Germany; Pamela Byrne, Food Safety Authority of Ireland and Monique Raats, University of Surrey / UK. The paper builds on the discussions of the European Commission FOOD 2030 workshop entitled ≪Smart Personalised Nutrition≫, that was held on the 16th of June 2016 in Brussels. It also draws on knowledge gained with the EU-funded research project “Food4Me” elaborating i.a. on health benefits of individual biomarkers-based nutrtional advise

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

CHANGING HOUSEHOLDS AND FOOD

TREND

The number of single-person households and people with different life styles is on the rise worldwide. This is also associated with distinctive food-related consumption behaviour.

SHORT DESCRIPTION

The number of single-person households in the EU is on the rise, amounting to 30% of the EU's households in 2011 [1].

Single-person households are a very heterogeneous group. For the UK, it is reported that around half of the individuals in single households were of working age while the other half were aged 65 years and over. In general, the number of single-person households has been growing mainly because the total number of aged persons has been growing [2].

The food-related consumption behavior of single-person households can be seen as distinctive. They tend to prefer eating out or consuming bought meals over cooking by themselves [3]. In case they cook for themselves, they need smaller portions, not family size packaging, otherwise this would raise waste of food.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

Ageing and changing demography result in more healthy life years, but often also in more years living on one's own. There is a decline of the traditional nuclear family and especially young urban people choosing different lifestyles. People often commute to work and study which results in less time availalble to purchase and prepare food.

In addition, the number of people of working age who live alone has increased sharply in the last few decades even though the number of multi-person households of working age has remained broadly unchanged [2].

All this results in more individualised lifestyles, and different food-related behaviour.

CONSEQUENCES ON FNS / SOCIETY

Convenience is important, which means more eating out and a spread of delivery services. On the whole it is desirable to promote more health delivery services and more healthy choices in eating out. These forms of taking in food seem to prevail in the future, so it is of importance they become healthy.

Smaller portions of meals are being prepared which in turn needs smaller packages in food retail and packaging. However, this would result in more packaging materials.

CHALLENGES – NEEDS FOR R&I STRATEGIES

There is an open question whether people who live alone take less good care of themselves. This would lead the way to more R&I on how healthy liefe styles and food-related behaviour can be facilitated in these target groups.

For small/single households increased food waste is one undesirable consequence of too large packages because it results in throwing away of stale food because it was not possible to use it up before expiry date.

Solutions could be:

- Longer shelf life of products would help consumers to meet expiry date even if packages are large.
- Alternatives for leftovers
- More on the side of innovation (not so much research)
- Business models for healthy home deliveries,
- more intergenerational stylish and healthy offers for eating out (university campus restaurants accessible for seniors as well as students)

EXAMPLE REFERENCES

[1] OECD Family data base, 2015 http://www.oecd.org/els/family/database.htm

[2] G. Palmer Single person households Joseph Rowntree Foundation, York (2006)

[3] P.K. Jo The effects of the economic characteristics of single-person households on the food service industry. Korean Journal of Community Nutrition, 21 (2016), pp. 321-331

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

GLOBALISATION OF DIETS

TREND

This trend includes the increased popularity of *ethno foods* (Japanese, Turkish, Egyptian, Mexican, African, Korean, etc., cuisines) as well as the increased *availability of ingredients* for diverse cuisines in local supermarkets. There is a link to migration, travel and global communication

SHORT DESCRIPTION

Diets, even in the poorest countries, are increasingly affected by the growing global nature of food trade and trade-related industries. The access to ethnic cuisines (Mexican, Japanese, Egyptian, African, etc.) has risen in many countries over the years, the availability of ingredients, and exotic fruits and vegetables has been increasing considerably. Part of this trends includes fusion cuisine which brings culinary approaches of different ethnicities together, such as in *Indian sushi*.

On the whole this has led to a greater variety of food than our parents or grandparents once had in many countries. This is promoted by migration which per country raises the availability and demand for certain food traditions more than for others.

But there is a counter trend as the same offerings over countries become more homogenized and people tend to rely on a diminished variety of plants, as a few staple crops like wheat and maize (corn) and soybeans come to displace regional crops.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

The globalisation of diets is in large part driven by (increased) global migration, travel and communication. Migrants bring their gastronomies with them, and not seldom find a job in the food business, for example by opening a restaurant. People who travel the world come home with an appetite for the food they have discovered abroad The increased popularity of certain diets, like vegetarianism, may also contribute to an interest in different cuisines. TV and internet contribute to familiarizing us with new and exotic dishes and make looking up the recipes easy.

Companies selling certain foods also actively target new markets. Developments in transport have also made it possible to distribute food products all over the world.

CONSEQUENCES ON FNS / SOCIETY

The globalisation of diets has created a much larger range of cuisines and ingredients to choose from. This increased variety can make eating more interesting and also offers a wider range of healthy and palatable options. Increased demand for certain products may provide economic opportunities for producer countries. On the other hand, this demand for new products, especially in case of a 'hype', may also cause problems in producer countries. Increased production to keep up with demand may deplete local natural resources like water, or an increase in price may place products out of reach for local populations.

A counter effect of this increased globalisation may actually be a homogenization of diets, with certain staple crops like wheat and corn displacing traditional, local crops, causing a loss of biodiversity.

And then there is the loss of traditional (healthy) diets that are displaced by less healthy, often western diets. A factor in this is the convenience of western food, but also the status it may have in other parts of the world, created by the general export of western (pop)culture.

CHALLENGES – NEEDS FOR R&I STRATEGIES

- How to counter the problems, particularly in producer countries, that are created by an increased demand in new food products considered trendy, and/or the increased global production of certain staple crops.
- The (health)issues associated with the export of western diet to the rest of the world.
- Food safety issues associated with new products and food supply chains.

EXAMPLE REFERENCES

[1] Khoury, C. K., A. D. Bjorkman, et al. (2014). "Increasing homogeneity in global food supplies and the implications for food security." Proceedings of the National Academy of Sciences.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

CONSUMER ENGAGEMENT

CHALLENGE/TREND

Consumers cannot be placed merely at the receiving end of the food supply system. They are not just customers who demand what is supplied, but they are self-organized actors pursuing their own interests according to their values and degree of information, thus driving the development of a future food supply system.

SHORT DESCRIPTION

Consumer engagement means to not only see the consumer as a passive recipient of what food is provided through the food system. As active players and participants, consumers want to make sure that solutions are developed that are not only accepted but also implemented by them.

Another perspective on consumer engagement is that of the self-organization potential of consumers in purchasing and acquiring food that is regional, seasonal and comes directly from local agriculture. Food purchasing cooperatives. Foodcoops often have the opportunity to purchase organic food at cheaper prices, but also have more ambitious goals, for example:

- Promotion of organic agriculture: abandonment of pesticides, fertilizers and genetic engineering.
- Support of local farmers with direct marketing and short transport routes.
- Take responsibility for the impacts of own consumption and products purchased.
- Promotion of fair trade and the regional economy

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DEVELOPMENT-DYNAMICS AND DRIVERS

Consumer engagement intends to lead to feasible alternatives to incumbent practices in matching hidden supply and demand (e.g. support local supply, food waste etc.) and hence become instruments for "nudging" that undermine environmentally detrimental practices. Often, they have an explicitly local role like cultivating local values and responding to local symptoms of nature problems.

The digital revolution has fundamentally altered the way we interact with each other or with industry [1]. The possibilities of networking through social media and thus mobilizing via interst groups etc. are a strong driver behind this trend. Companies also realise that consumer engagement can be used in product development so that potential customers identify themselves more with the end product.

CONSEQUENCES ON FNS / SOCIETY

The consequence of increased consumer engagement is a more direct influence of consumers on the food system, and potentially more knowledge about consumers on part of the food industry and vice versa. Sharing all information about a food product could provide the competitor with an unwanted advantage. Thus food manufacturers are holding back with information to protect intellectual property rights.

CHALLENGES – NEEDS FOR R&I STRATEGIES

From the viewpoint of food suppliers, understanding consumer engagement and the underlying motives is crucial. Measures to gain understanding are

- Open science and innovation to better understand consumer wants and needs (shared decision making on R&I)
- Community based education initiatives to allow consumers to better understand and directly contribute to the food system
    - Community based participatory research
    - Service Learning
- Other co-creation initiatives e.g. Xplore Health initiatives
- Proactive identification of unmet needs (e.g. R&I agendas, Science Shops)

EXAMPLE REFERENCES

[1] Jacobi Cargill, R., H. van Trijp, R. Fernández, ETP 'Food for Life', Bots, M., Bayer CropScience, J. Jacobi, K. Metzlaf, U. Schurr, A. Malyska, ETP 'Plants for the Future' FOOD FOR TOMORROW'S CONSUMER

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

TRADITIONS AND DO IT YOURSELF

TREND

Getting more involved in cooking fits in with the current DiY (Do-it-Yourself) trend. Consumers show increasing interest for products that are perceived as more traditional and homemade, which is related to values like health, sustainability, authenticity, ethics, and emotional and social needs.

SHORT DESCRIPTION

Do-it-yourself instructions on and offline, in videos and blogs, as well as in books and magazines, about recipes, cooking tips, and natural life and pleasure are becoming increasingly popular. Gardening and cooking are a new way of life. Many people use these activities to slow down and realise a lifestyle closer to nature and seasons. It serves as a contrast to a technological world, with its inscrutable ways and processes.

Growing parts of the population fancy cooking as a joint activity, with fresh and regional ingredients of good quality, if possible self-grown. They try out previously unknown products and food combinations while using old techniques, such as making jam. They share their experience with friends and acquaintances directly or through social media networks.

DiY seems to generate satisfaction and is rooted in values and needs like health, sustainability, authenticity, ethics, and emotional and social needs.

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DEVELOPMENT-DYNAMICS AND DRIVERS

A loss of consumer confidence in the food industry is a common motive for DiY. Also because of food fraud, many people want to know where their food comes from and under what conditions it is produced. A common way to do that now is by producing food by oneself. In larger cities, urban gardening or urban farming has meanwhile become a trend. Whether growing flowers or harvesting vegetables, everything is possible.

DIY food is becoming a lifestyle, pushed via social media channels, food blogs, but also via simple instructions that are available on the Internet for preserving and preserving.

Urban green areas are supposed to bring people together, provide them with food and make the cities more beautiful and sustainable. The United Nations Agricultural Organization, the FAO, promotes urban agriculture in the exploding cities of Africa to supply the population.

CONSEQUENCES ON FNS / SOCIETY

Niche markets develop through special preferences of DiY promoters. Increased awareness of food quality and the need for joint and enjoyment-oriented cooking and eating are a countertrend to fast and convenient life styles and culture. The higher awareness for food ingredients, their origin or food processing methods could also lead to an impact in food production and consumption of healthy food products.

CHALLENGES – NEEDS FOR R&I STRATEGIES

When DiY food is offered for sale on the market, and not only produced for personal consumption legal aspects need to be considered. In the EU when you start a food business you are regarded as a 'food business operator'. It is your legal responsibility to make sure that your new business complies with food law and produces safe food. The main purpose of food law is to ensure a safe food supply and to protect consumers' interests in relation to food.

National laws, when a company is regarded as a food business operator, need to be considered as well as EU regulation. Examples for regulations and guidelines are given in [2-4].

EXAMPLE REFERENCES

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[2] FSAI (2016): Guide to Food Law for Artisan/Small Food. Producers Starting a New Business. ISBN 1-904465-67-6. https://www.fsai.ie/details.aspx?id=9480

[3] http://www.foodauthority.nsw.gov.au/retail/home-based-mixed-businesses

[4] https://www.fastcompany.com/3061498/the-food-sharing-economy-is-delicious-and-illegal-will-it-survive

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

SOCIAL MEDIA AND FOOD

TREND

Social media have changed the way we eat and what we eat. There is a trend towards food that is considered aesthetically pleasing: it has to be “clickable and likable”. Internet has made new culinary worlds accessible and websites and blogs for recipes are replacing traditional cook books. People are also increasingly influenced in their food choices by bloggers and what they read online.

SHORT DESCRIPTION

Platforms like AllRecipes get increasing attention and visits from (home-)cooks around the world. What also influences food behaviour are dedicated food bloggers who broadcast their food. [1]

Industry watchers observe that online food promotors have more outreach than TV personalities and branded content. The often DIY-nature of their content emphasized by posts of how the food is being prepared can give a feeling of relatedness. This is what makes them attractive to their many followers who take inspiration from them. [2]

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DEVELOPMENT-DYNAMICS AND DRIVERS

A main driver behind this is the ever-increasing possibilities and availability of the internet and social media. Platforms like Instagram make the aesthetics of food more and more important, and nearly everybody has a smart phone allowing immediate access to social media. It has become commonplace to look for information and inspiration online when it comes to food and to share what or where you are eating. Everybody can proclaim their own ideas about food online and certain bloggers have a large following, influencing people based on their own knowledge and beliefsabout food and their food choices.

Another driver behind this is the growing distrust that many people have in traditional authority and science, leading them to put trust in people online whom are relatable. Shared personal experience builds a perceived relationship which is more emotionally reassuring than factual information from science and experts.

Companies also use the possibilities offered by social media to push their brand and products.

CONSEQUENCES ON FNS / SOCIETY

The ease and speed with which information can spread via the internet or even go viral, can lead to (global) food trends and food hypes, like food in jars or the popularity of so-called super foods. The aesthetics of food has also become very important.

These food trends and hypes, often propagated by online influencers, are not necessarily healthy, responsible or sustainable and tend to have very little to do with science.

Rapid shifts in demand for certain products may create problems on the production and distribution side.

CHALLENGES – NEEDS FOR R&I STRATEGIES

- How does viral growth and diffusion via social media work?
- How can the spread of incorrect or even harmfull information about food online be countered -> better education of people about what ‘good food’ is, but also about how to be media-savvy?
- How can the trust of people in science, and access to correct information be increased?
- The ability of the production and distribution side to adapt to rapid changes in demand

EXAMPLE REFERENCES

[1] http://www.thisisinsider.com/how-instagram-has-completely-changed-the-way-we-eat-2017-8, last accessed March 25th, 2018

[2] https://www.brandwatch.com/blog/react-food-influencers-2017/, last accessed March 25th, 2018

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

5. Market Economy, Retail and Logistics

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

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CONCENTRATION IN FOOD RETAIL MARKETS

CHALLENGE/TREND

Retailing is one of any economy's most visible activities. Retailing refers to the sale of goods or services from companies to individual end-consumers. The last 20 years have seen a number of important joint-ventures, mergers and acquisitions in the retail sector, either to enter into new markets, or to consolidate positions on domestic markets during a period marked by increased international competition as well as the emergence of e-commerce.

SHORT DESCRIPTION

Retailers have an important role for the food and nutrition security as they occupy a unique position in the lifecycle chain of products as a 'gatekeeper' between producers and consumers. Modern grocery retail sales account for 54% (in 2012, same in 2004) of the total edible grocery sales in the EU28. Edible grocery sales represent 42% (in 2012, 43% in 2004) of total EU retail sales [1].

In 1999, Carrefour's merger with Promodes created Europe's largest and the world's second largest retailer to Wal-Mart. Other notable mergers at this time involved Rewe/Meinl in Austria in 1999 and Makro/Metro in 1998. The mergers and acquisitions have continued well into 2000s, whereby at the pan-European level, the top 10 European retailers accounted for 26% market share in 2000, compared to 30.7% in 2011, representing an increase of +4.7 points [1].

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

In the EU, the concentration of the total food retail markets has increased the top 5 food retailer market share at national levels and exceeded 60% in 13 EU Member States corresponding to 52.8% of the EU population in 2011. [1]

The concentration pattern in the USA has been similar to that of the EU during the same period. The share of total sales of top 20 food retailers increased from under 40% in 1992 to above 65% in 2016, whereby top 8 food retailers accounted for 55% of the total sales [3].

e-commerce has also developed significantly in the food retail sector over the past decade. This sector has caught on with consumers and developed in a number of markets, most notably the UK, France and Spain. e-commerce food sales are still marginal and relatively small across Europe, however, in developed markets such as the UK, online grocery sales currently account for nearly 3% of total food sales.

CONSEQUENCES ON FNS / SOCIETY

The EU has been increasingly examining the concentration of retailers and found that the direct consequence is the bargaining power imbalances in trade relations between the actors in the chain, potentially leading to unfair trade practices (UTPs). UTPs may occur when weak parties have no real alternative to the commercial relation at hand; when one of the parties depends on its counterparts due to factors such as technology and know-how; when one of the parties can exploit informational advantages to the detriment of the other party; in case of incomplete contracts, which leaves room for strategic behaviour during the course of the negotiation, execution and finalisation of a contractual relationship. [2]

Private labels, sometimes referred to as retail 'own-brands', are goods for which retailers directly contract manufacturers to produce and then sell under their own brands. These products are typically sold at a discount and serve as a lower cost alternative to major national and international brands. Nonetheless, some retailers also develop high-end private label products. [1]

Private labels are increasingly being seen by food retailers as important tools for building client loyalty and strengthening brand image. Thus, beyond generic and 'mimic' private labels, which are designed to provide low-cost alternatives or directly compete with manufacturer's brands, retailers have increasingly developed high quality private labels brands that compete side by side with manufacturer's brands or specifically positioned product ranges, such as organic.

Globally, penetration of private labels is high in Europe, where they can exceed 40% market share in countries such as Switzerland and the UK, compared with an average in the US of 18% market share in 2011 [1]

Other technological advances are apparent outside the shop, such as retail grocery price comparison websites (e.g. www.mysupermarket.co.uk), and the emergence of digital walls in subway stations where groceries each have a QR code that the shopper can scan with a smartphone camera, adds to its shopping list, pay using the phone and have the groceries delivered.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Innovation in the food retail sector is directly linked to the margins. The Joint Research Centre of the European Commission finds that, where present, reverse margin practices compensate retailers with the risks associated with making shelf space available for new products. In addition, reverse margin practices act as a sort of screening-signalling mechanism. On the one hand, the charges related to these practices will be accepted only by those suppliers who are sure that their innovation will be successful. On the other hand, consumers can also be sure that what they see on the shelf is a successful innovation. As far as the negative relationship between reverse margin practices and innovation is concerned these practices increase the costs of innovation and require a sizeable capital, especially for relatively small innovators. Further, these are sunk costs for a specific transaction. This in turn increases suppliers' vulnerability to unfair termination of the commercial relationship or retroactive changes to the contract and allows retailers to extract a higher share of surplus created by a given transaction. [2]

With the emergence of data economics, retailers can be expected to have an even more important role in the FNS whereby they have access to vast amounts of consumer data, which could be used to improve consumer experience rather than for their simple use for margin calculations and stock programming.

As far as the innovation for private labels are concerned, although they contribute to choice and have beneficial effects for the society up to a certain point, beyond that "tipping point" the effect turns negative for innovation.

EXAMPLE REFERENCES

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

NEW SHOPPING BEHAVIOUR

CHALLENGE/TREND

Food services are emerging that include personalized recipes, diets, delivery and ingredient customization in all possible combinations around people's lifestyles. Social use of technology is also affecting consumer behaviour. Time is a very important consideration when choosing what to eat and can counteract or even overrule nutrition and health factors if a choice needs to be made.

SHORT DESCRIPTION

A new wave of meal kits and customized food services are gaining momentum in developed markets, demonstrating a new trend towards food customization and enabling technologies that make it easier for people to create, prototype, and market unique food offerings.

Moreover, with the social use of technology, consumers are starting to define themselves less by how many things they own and more by how curated their lives are in terms of possessions and experiences. This is expressed through seeking experiences and products that reflect the personal brand they promote on social media.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

Over the past decade, consumers have developed a sense for what is authentic and what is mainstream for mass-consumption. This has led to a rise in consumer behaviour making values-based judgements about what to buy and where to shop. These engaged consumers believe that their purchasing habits have an impact on the society and for the world.

A Global Corporate Sustainability Report published by Nielsen indicates that, globally, 66 percent of consumers are willing to spend more on a product if it comes from a sustainable brand. Millennials gave an even more impressive showing, with 73 percent indicating a similar preference. Simply put, consumers want the companies they buy from to practice sustainability, strong ethical behavior and transparency. Customers want to buy an honest brand. Retailers have to be authentic and transparent, but they also need to communicate this in a sophisticated and trustworthy way, or consumers may turn to another brand [1].

CONSEQUENCES ON FNS / SOCIETY

Digital platforms have been changing consumption behaviour by providing users with a convenient and high-quality food, consumption data, and speed of delivery. The availability and use of mobile technologies also enable social media to interact with consumers at any moment.

The engaged consumer movement is growing. One third of UK consumers, for example, claim to be very concerned about issues regarding the origin of products. Authenticity is especially key for spending of consumers of all ages. It is identified that millennials are having a deep impact on the generations that came before them (Boomers, Gen X etc.) as well as the one that comes next: commonly referred to as Gen Z. [2]

On the other hand, online food-delivery platforms are expanding choice and convenience, allowing customers to order from a wide array of food suppliers with a single tap of their mobile phone.

E-commerce is well suited to specialty retailing because it allows companies to offer greater product selection in a category than would typically be available in brick-and-mortar stores. Online retailers can do well by fulfilling unique customer needs, such as the desire for better-for-you foods. [3]

CHALLENGES – NEEDS FOR R&I STRATEGIES

To win customers today, businesses need to adapt to consumer behaviour and preferences more than before and reflect the consumer-centric message throughout their production line. The innovation also needs to follow consumer demand and increasingly take into account and adapt to individual consumer preferences.

While technology enables increased food access, personalisation as well as new business opportunities in urban areas, use of technology for low-end discounters and price transparency can enable food access in low-income neighborhoods and communities, contributing to FNS.

The increasing consumer awareness and engagement as well as the social media could also result in rejection of innovation or innovative products, independent of the innovation's health safety and economic credentials. This could discourage incentives for innovation while on the other hand rechannelling financing to consumer-driven innovation projects and products.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

SHORT FOOD SUPPLY CHAINS

CHALLENGE/TREND

Short supply chains involve as few intermediaries as possible, connecting local suppliers with local consumers more directly compared to conventional (longer) supply chains.

SHORT DESCRIPTION

Short food supply chains enable small-scale enterprises to establish food supply chains that are 'independent' from the wider systems. By cutting out some of the intermediary stages between producers and consumers – such as wholesale and distribution – short food supply chains create a new consumer-producer relationship, which could be beneficial for both as well as for the environment.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Short food supply chains occur as territorial innovations taking part in the reformulation of local dynamics through the emergence of socio-economic practices whose implications relate to the different dimensions of sustainable development. They take part in the empowerment not only of producers but also of the set of territorial partners around a mobilization in favour of sustainable food.

CONSEQUENCES ON FNS / SOCIETY

Local food supply chains seem now to be considered as a serious alternative to global ones in terms of sustainability.

The Eurobarometer survey found that the utilisation of short food supply chains leads to fairer prices for farmers, given fewer middlemen, ensuring farmers get a larger slice of the profits. [1]

This can develop trust and a new relationship model between producers and consumers. Local economies could also benefit from this newly emerging relationship by new job creation.

Local markets also give consumers better access to fresh, seasonal produce and have less of an impact on the environment due to reduced production and transport associated with local foods.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Sourcing food locally provides food service companies with the opportunity to deepen the relationship with the customer. It can bring the food service company closer and it distinguishes them from others. But growing demand brings challenges, as food service companies need to cope with a mix of short and long supply chains while maintaining food quality standards.

The role of digital technologies need to be recognised and taken up by the short supply chains, as these can increase consumer reach as well as revenues of the short supply chains. The disruptive impact of digital technologies combining the peer-to-peer potential with the capacity of e-commerce platforms to aggregate small suppliers and creating a single point of transaction for consumers. Digital food hubs are thus promising examples of those disruptive business models [2].

EXAMPLE REFERENCES

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

CHAIN CLUSTERING ALONG THE FOOD SUPPLY CHAIN

TREND

Across the food sector a significant horizontal and vertical restructuring is happening. Un-precedented consolidation runs along and across the seed, agri-chemical, fertilizer, animal genetics and farm machinery industries, while creating ever-bigger players in the processing and retail sectors. This consolidation along the food chain has made each node more reliant on a handful of suppliers, depriving their ability to choose what to grow, produce or to sell.

SHORT DESCRIPTION

Within the last years several high-profile deals have happened in the range of agri-food sectors - often with a view to linking different nodes in the chain. Especially the following parts of the food chain a few key players dominate the market on a global scale:
in the **agro-chemical** (seeds and fertilizers) **industry**: Examples are the $130 billion merger between US agro-chemical giants, Dow and DuPont, Bayer's $66 billion buyout of Monsanto, ChemChina's acquisition of Syngenta for $43 billion or its planned merger with Sinochem in 2018. This places 70% of the agrochemical industry in the hands of only three merged companies. Combined with new information technology big data analysis connects inputs - seeds, fertilizers, and chemicals - to farm equipment and retailers to consumers in unprecedented ways in the hands of a few big players.
In the purchase and **trade of crops and semi-finished food products** 80% of the trade of grain 80% goes through three companies.
In the **supermarket** sector in Europe and more and more in other parts of the world there is a limited amount companies behind the supermarkets and their influence towards the food suppliers has increased significantly.
In contrast to these sectors the position of the food- and drink industry is less dominant, with an average of 20 percent of the market. However, this position differs per product and country, big companies dominate for example the global market of baby formula and soft drinks.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Financialization – i.e. the increasingly powerful role of financial actors, motives and trends in shaping global economic activity – has become a major driver of corporate consolidation across various sectors as investors demand higher and shorter-term payouts. The goal of alliances is mostly to increase the command and control of fewer companies over a wider range of input decisions. [1] Merging and acquisition of companies is often driven by the intention to maximize shareholder value, increase and/or protect market share, expand to new geographical markets, acquire new technologies, services, or intellectual property or to gain control over supply chains. [1]

CONSEQUENCES ON FNS / SOCIETY

Monopolies in the food system chain will make it more difficult to innovate or change the food system, if the direction of change is not in the interest of these companies. In general markets with high concentration are considered less competitive and at greater risk of collusive and coercive behaviour [1].

Less diversification of food will mean limitation of 'freedom' of choice for both the farmers as well as the consumer. For the farmers this might make their occupation less attractive both from an economic point of view as well as when looking at the work satisfaction. Furthermore the barriers of entry into a production chain controlled by a handful of companies is much higher, as they seek to maintain their positions by creating barriers to entry for new firms and establishing mutually beneficial pricing arrangements.

The capability of a food system to adapt to exogenous shocks reduces in very rigorous and rigid systems. The dependency of each node, especially the dependency of farmers on seeds, fer-tilizers, machinery etc. from one company increases again reducing the opportunity to innovate.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Companies have shifted R&D resources to the least risky modes of investment, e.g. focused on protecting patented innovations and creating barriers to entry. Cartels are very difficult to identify, given that companies are ostensibly in competition and are not acting explicitly for mutual advantage. Also data from different sources than US are missing and prove an interesting field for R&I in the EU.

The stimulation of start-up companies/ innovation in those sectors where innovation/ diversification is difficult due to dependency on big companies working towards both business challengers as well as stimulating diversification of crop species and protein sources can be given as another example for needs for R&I strategies.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

PHYSICAL INTERNET (LOGISTIC)

CHALLENGE/TREND

The concept of Physical Internet was introduced as a framework for Internet of Things in the context of transport of goods and logistics networks, i.e. uniquely identifiable objects receive a representation in a virtual world. “Intelligent" containers store information about their content, but are also capable of dynamically optimizing transport flows. The goal of the Phyical Internet is to use the principles of sending data packets through the digital internet in order to create more efficient and sustainable logistics

SHORT DESCRIPTION

Physical Internet is a concept aiming to transform the way physical objects are handled, moved, stored, realized, supplied and used, aiming towards global logistics efficiency and sustainability. [1, 2] This is attempted to be achieved by applying concepts from internet data tranfesr to real-world shipping proceses.

As the Logistics and Supply Chain Management is a very fragmented sector and the concept of Physical Internet also includes other fileds from software and automation engineering, communication to business and social and urban issues the challenge to achieve a common functioning Physical Internet is very high.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Logistics and supply chains develop towards a cheaper and more efficient, but at the same time a more customized and service-oriented sector, supported by a full integration and synchronization of manufacturing, inventory and transport chains, i.e. supply chain integration. At the same time the ultimate challenge will be solve the societal, economic and environmental unsustainability of logistics to contricute to both industry competitiveness and the EU policy targets.

CONSEQUENCES ON FNS / SOCIETY

Logistics and Supply Chain Management is a very fragmented sector, in which a broad variety of companies and associations intervene.

The domain scope for future Physical Internet research, development and innovation is wide. It encompasses the fields of logistics, transportation, supply chain management and operations research; industrial, mechanical, civil, software and automation engineering; information and communications technology as well as business, human, legal, sociala and urban fields to name a few. [1,2]

CHALLENGES – NEEDS FOR R&I STRATEGIES

For the full realization of Physical Internet, innovations in many areas are necessary. This includes not only to new business models, but ranges from topics regarding infrastructure, machines and tools as well as data exchange.

It is essential to clarify if generate innovative potential from the area of Physical Internet, or whether the starting point for innovations can be seen in the underlying (digitized) logistics process.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

6. PACKAGING AND WASTE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

BIOBASED PACKAGING

TREND

Bioplastics are not just one single substance, they comprise of a whole family of materials with differing properties and applications. According to European Bioplastics, a plastic material is defined as a bioplastic if it is either bio-based, bio-degradable, or features both properties. There has been an increasing trend towards replacing conventional fossil-based plastics with bioplastics. Within the next years, global production capacity of bioplastics is expected to reach a level of 7.85 million tonnes in 2019.

SHORT DESCRIPTION

There are three groups of bioplastics, each with their own characteristics [1]:

- Bio-based (or partly bio-based), non-biodegradable plastics, (e.g. bio-based polyethylene or PET), bio-based technical performance polymers (e.g. numerous polyamides, or polyurethanes)
- Bio-based and biodegradable plastics, such as polylactic acid (PLA), polyhydroxyalkanoates (PHA), polybutylene succinate (PBS), or starch blends
- Plastics based on fossil resources and biodegradable ones, such as polybutylene adipate terephthalate (PBAT), that may be produced bio-based in the future.

The use of bioplastics as food packaging materials is subjected to different limitations, restricting their use. Besides a higher price level compared to conventional plastics, the concerns on availability of raw (biomass) material as well as on the use of land to produce bioplastics, there are major limitations on the functionality. [4]

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DEVELOPMENT-DYNAMICS AND DRIVERS

The European Strategy for Plastics in a Circular Economy lays the foundations to a new plastics economy, where the design and production of plastics and plastic

products fully respect reuse, repair and recycling needs and more sustainable materials are developed and promoted.

The petrochemical-based plastics are non-biodegradable and therefore lead to environmental pollution if not disposed accordingly. Because of this growing problem of waste disposal and non-renewable source with diminishing quantities, renewed interest in packaging research is underway to develop and promote the use of bioplastics in food industry. Bioplastics have been increasingly used as packaging materials in the field of food packaging. [2] On the one hand, the growing environmental awareness of consumers as well as the knowledge about the finite nature of the planet's fossil resources are spurring the demand for bioplastic materials and products. On the other hand, big brands and manufacturers are looking for innovative ways to reduce their environmental footprint and are tapping into the many benefits and advanced technical properties bioplastics have to offer. [1]

CONSEQUENCES ON FNS / SOCIETY

The bioplastics aim is to emulate the life cycle of biomass, which includes conservation of fossil resources, CO2 production and water. [1]

On the level of raw materials, use of recycled materials or use of renewable resources are two strategies to reduce CO2 emissions and the dependency on fossil resources. The production process is another level where adjustments, e.g. toward a more energy-efficient process, can be made. A final level where efforts can be done to increase sustainability is waste management. Next to reuse and recycling of used materials, production of packaging which is biodegradable and/or compostable contributes to reducing the municipal solid waste problem. Indeed, bioplastics could potentially have a positive role to play in the transition to a true circular economy, but only if their development is based on consuming within the limits of the planet, ethical and local sourcing, resource efficiency, waste prevention, reuse and recycling. [3]

CHALLENGES – NEEDS FOR R&I STRATEGIES

Bioplastics, due to their often complex design, create difficulties in collection and recycling processes - therefore, as with conventional plastics, they are likely to end up in landfills or incinerators or risk polluting the marine environment. On top of this, false assumptions on biodegradability may increase littering, contaminate recycling streams and increase bio-waste management costs. Rapid growth in projected production capacity will also create increased pressure on land areas, particularly outside of Europe, triggering environmental and social impacts. [3]

Nowadays biobased packaging materials are mostly used to pack short shelf life products, like fresh fruits and vegetables, and long shelf life products, like pasta and chips, which do not need very high oxygen and/or water barrier properties. However, the inventory of films shows a wide variety in properties, which could make them also applicable as a packaging material for other food products with stricter conditions, like MAP packaging. Strategies to investigate and improve properties of bioplastics have to be developed to ensure functional properties as conventional packaging material, while considering the whole life cycle of the product.

EXAMPLE REFERENCES

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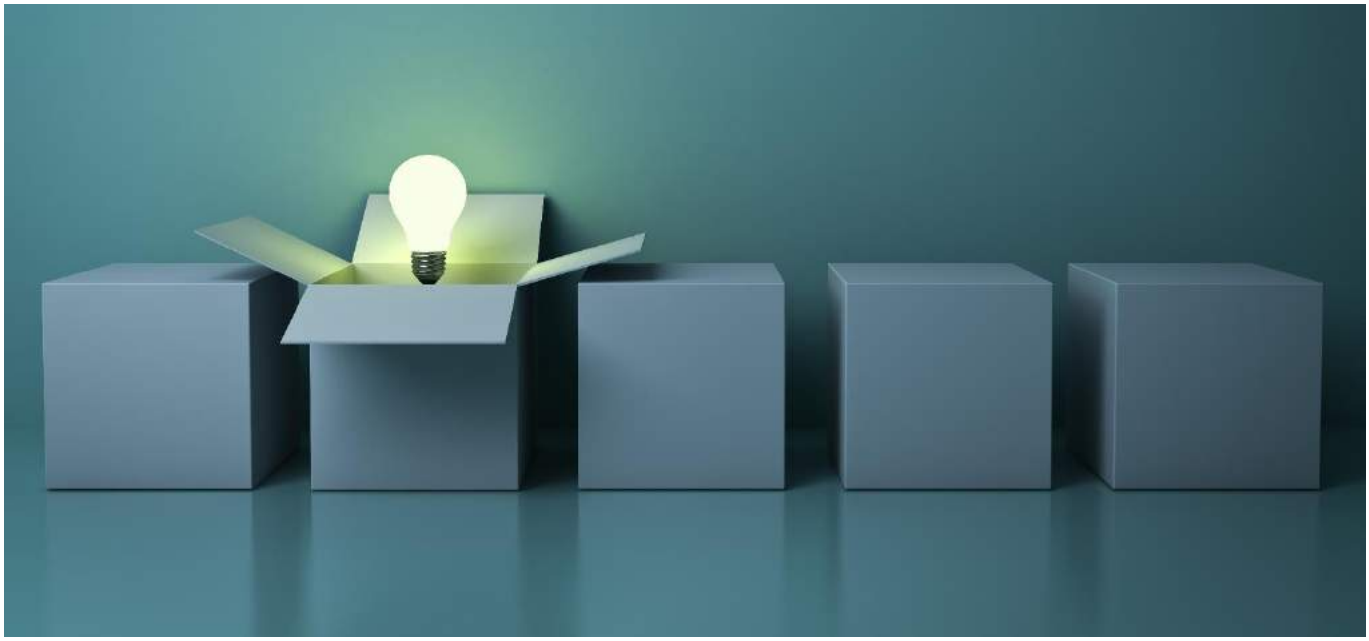
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

PACKAGING 4.0

CHALLENGE/TREND



Packaging 4.0 goes beyond active and intelligent packaging providing an interface to a rapidly evolving digital world, implementing Industry 4.0 concept into the food system. Packaging 4.0 allows digital connectivity and new functionality that also engages the consumer. Intelligent packaging solutions will communicate actively within the value chain, manufacturing, distribution and the consumer's home environment [1].

SHORT DESCRIPTION

Active packaging is a type of food packaging with an extra function, in addition to that of providing a protective barrier against external influence [3]. Intelligent Packaging are "materials and articles that monitor the condition of packaged food or the environment surrounding the food" [2].

The concept of Packaging 4.0 combines these functionalities with digital communication and will thus lead to affordable scalable digital technologies that can enhance consumers' engagement while providing interfaces along the supply chain. Packaging 4.0 will allow not only active communication with manufacturing and distribution systems, but also with home appliances in the home environment, like refrigerators, providing active information to the consumer.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

The goal in this "Packaging 4.0" era, is to build intelligent systems, services and supply chains that lead to a more competitive system. The key to success in this pioneering phase of transition, however, are partners. Tetra Pak and SIG for example invest in technologies in the areas of the Industrial Internet of Things (IIoT), the cloud and predictive applications, to name a few, combining the stack of technologies to create Industry 4.0 offerings. [4, 5].

The overall aim is to make logistics easier and communication with and between manufacturers better and to increase food safety and security along the whole production and distribution chain. On the consumer side the idea of reducing food waste by communicating packaging is following the trend of responsible and environmentally conscious consumer. The possibilities to add convenient functionalities and increase information through communicating packaging are another benefit for consumers.

CONSEQUENCES ON FNS / SOCIETY

Packaging 4.0 like Industry 4.0 is all about connectivity and efficiencies. All manufacturing machinery, from an early point of food processing to packaging and logistics, cannot be allowed to operate in a silo. The equipment in all stages needs to be modular, smart and fully connected, capable of improving a manufacturing company's packaging speed, and able to deliver customised products and effective, scalable production. Packaging material itself needs to be affordable, scalable and must also be compatible with packaging recycling.

The major issue running along with all trends and developments in data exchange and integration is the data management, usage and storage. All data related to consumers could potentially be misused for strategic marketing and manipulation, such as eating/buying habits of consumers. Thus careful handling of data and data protection need to be addressed and ensured.

CHALLENGES – NEEDS FOR R&I STRATEGIES

The concept of Packaging 4.0 will only work if the connection of all involved parties along the supply chain and interfaces is given. Systems must be able to communicate with each other to ensure exchange of information. As with all systems following the idea of Industry 4.0 or interconnectivity not only the technical aspects but also legal aspects and security of data that need to be investigated and handled with reasonable care. Transformation of systems will progress at different speeds and care must be taken that big players do not overrun small companies, who are not able to implement new technical solutions at the same level.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

REDUCTION OF PLASTIC PACKAGING

CHALLENGE/TREND

Plastic is an important and ubiquitous material but often the way it is used and discarded does not run along with the economic benefits of a circular and sustainable approach and harms the environment. The EU has recently published a vision for circular plastics economy. Regarding the food system responsible consumers ask for reduction of packaging - not only plastic - to avoid waste and environmental pollution, companies start rethinking packaging material taking sustainability into account.

SHORT DESCRIPTION

Mismanaged waste and marine debris have significant detrimental effects on wildlife, public health, and the economy. Especially plastics has become the focus of attention as million tonnes of plastic litter end up in the oceans every year and are one of their most visible and alarming signs of these problems, causing growing public concern [2]. The EU has launched a vision for circular plastics economy with the “New Plastics Strategy. However, studies show that the environmental costs of alternative packaging material as glass, tin, aluminium and paper can be much higher than of plastic material [3].

The reduction of waste and a more “circular” approach to achieve environmental and economic benefit is major issue with all packaging material. Increased consumer consciousness about the environmental impact and recent media campaigns on (plastic) pollution of oceans are strong drivers for this trend.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

The development of packaging material so far concentrated mainly on increasing shelf life of perishable goods and ensuring transportability. Due to its light weight and variable characteristics plastic can be applied ubiquitous and show big advantages over other packaging material. There is an urgent need to tackle the environmental problems that today cast a long shadow over the production, use and consumption of plastics. Recent media campaigns like the World Oceans Day in June 2018 have addressed the increased accumulation of (plastic) waste in the oceans and on land. Mismanaged waste and marine debris have significant detrimental effects on wildlife, public health, and the economy. [4]

Increased consumer awareness is putting pressure on food producers to use other packaging material and consider environmental impact. Furthermore, legislation and regulatives are guiding towards visions of circularity and sustainability (e.g. [1], [2]. [4] or [5]).

CONSEQUENCES ON FNS / SOCIETY

Rethinking and improving the functioning of such a complex value chain requires efforts and greater cooperation by all its key players, from plastics producers to recyclers, retailers and consumers. It also calls for innovation and a shared vision to drive investment in the right direction. The plastics industry is very important to the European economy, and increasing its sustainability can bring new opportunities for innovation, competitiveness and job creation, in line with the objectives pursued by the renewed EU Industrial Policy Strategy. [1]

Food and packaging producers are slowly implementing changes, not only for the reason to reduce their production costs, but also to contribute to the environment. There are a lot of changes that could be implemented to address the waste side for the items they produce, but the whole system needs to be considered, stranding from protection of foods to transport and logistics.

CHALLENGES – NEEDS FOR R&I STRATEGIES

The political debate around rapidly replacing conventional plastics with bioplastics or other materials hides the real issue: the pressing need to reduce all plastics use and in particular excessive, unnecessary and single-use plastics. Our overconsuming, throwaway culture is tied to a linear buy-use-dispose economy, and will not be solved by relying on technological solutions. Instead, we need behavioural and production change and for government priorities to be on prevention and reuse. [6]

Measures as Container deposit legislation (CDL) can be one of the many legislative actions proposed by lawmakers to curb the amount of debris entering the ocean. The European Strategy for plastics in a Circular Economy is another example of paving the way to reducing packaging material. Other measures may include reusable packaging, short food supply chains, package-free retail and a systemic change initiated in the innovation process [7]. The OECD has recently published a book including policy interventions addressing economic, environmental, technical and regulatory barriers [8].

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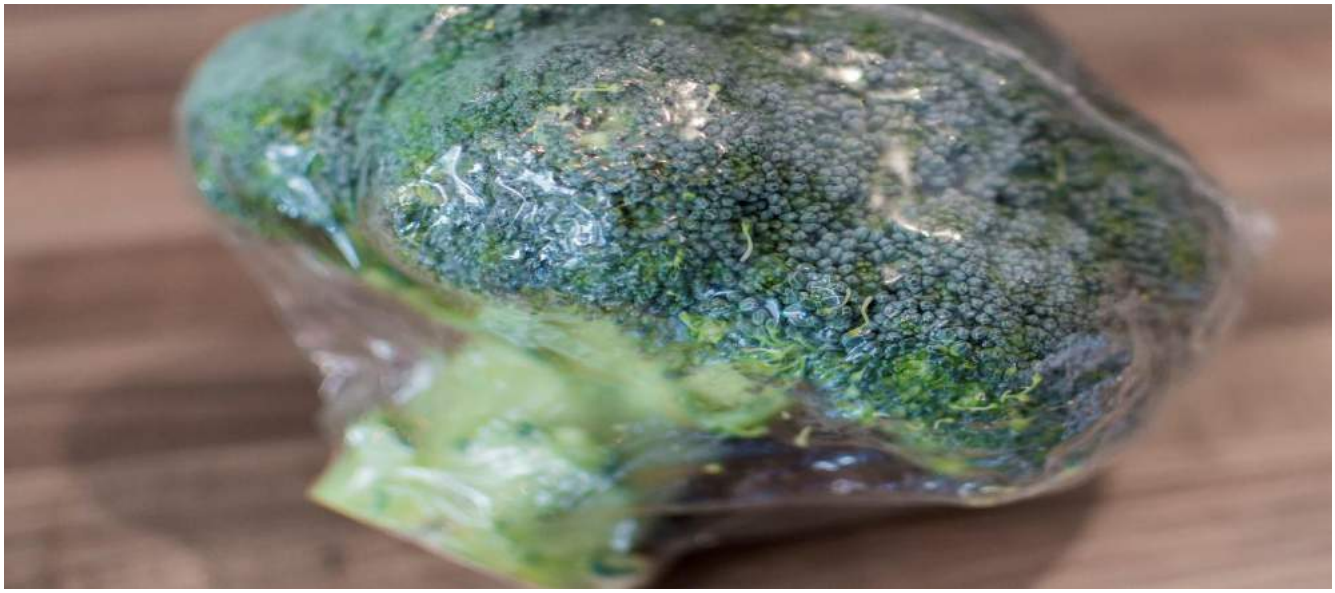
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

PACKAGING & HEALTH

CHALLENGE/TREND



Advances in processing techniques, preservation, and packaging have enabled the food industry to consistently supply consumers with a wide array of healthy and fresh products all year round. Food packaging can improve food safety by reducing bacterial contamination, prolonging shelf life, ensuring convenience in distribution and handling. On the other hand food contact materials can transfer chemicals to food with partly unknown effects.

SHORT DESCRIPTION

Food packaging does much more than simply hold a product. It keeps food safe and fresh, tells us how to safely store and prepare it, displays barcodes that facilitate purchasing, provides nutritional information, and protects products during transport, delivery, and storage. On the other hand, packaging material can also transfer chemicals into our food, with unknown health effects. [1]

In Europe food contact materials (FCM) are regulated under a framework regulation of European community law. Specific migration limits exist for some compounds and a positive list compiles monomers and additives that are authorized for use in plastic packaging and other materials based on a toxicological evaluation. [2,3] In most FCM a large number of non-intentionally added substances (NIAS) can be detected, which may be (geno)toxic or act as xenohormones. New detection methods and insights into the effect of chemicals lead to consolidated findings and potential new regulation on FCM.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

DEVELOPMENT-DYNAMICS AND DRIVERS

The main intention of packaging material is to get food safely from the point of manufacture to consumers' cupboards and refrigerators. Food packaging can improve food safety by reducing bacterial contamination. It has been proposed for example that increased use of packaging for fresh produce could prevent contamination with Salmonella spp., a leading cause of foodborne diseases. [1]

Negative aspects like environmental problems caused by littering of packaging material or the transmission of chemical hazards from packaging material to food have become topic of public discussion in the last years leaving a negative connotation.

In most food contact materials a large number of non-intentionally substances (NIAS) can be detected. Current detection methods may under-predict human hazard by failing to identify the full potential of a substance for endocrine activity (i.e. a chemical substance with hormone effect, a xerohormone). Within European food contact material legislation specific migration limits exist, that are continuously updated according to state-of-the-art scientific knowledge.

CONSEQUENCES ON FNS / SOCIETY

The positive effects of (plastic) packaging have been an argument for the use of sometimes extensive packaging material. Freshness, portion sizes, convenience and especially the food safety from producers to end consumers are of great benefit for the food system. Guaranteeing long shelf life and freshness results in less (food) waste.

However, pressure increases due to environmental problems and NIAS, that can be detected more easily, to change packaging amounts and materials or include waste management in the development process. Shopping behaviour of consumers may change with an increased demand for unpacked goods, creating a challenge for food industry to ensure freshness and hygiene, while still considering convenience.

CHALLENGES – NEEDS FOR R&I STRATEGIES

There are currently no reliable and cost-efficient methods for the identification and toxicological evaluation of all detected NIAS. Therefore, the use of in vitro bioassays was recently recommended by the International Life Science Institute (ILSI) and by the European Parliament to simplify the safety assessment of food packaging. [4, 5]

Results from these screening tests can fail to eliminate candidates with less favourable profiles early in development (precluding safety by design). Such failures may also prevent the identification of hazard potential in cases where it is easier, faster and/or cheaper to manage this potential than clarify whether the hazard is genuine with further testing (thwarting proactive management).

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

FOOD WASTE RECOVERY UP-CYCLING / WASTE COOKING

TREND

The FAO estimates that each year approximately one third of food produced for human comsumption in the world is lost, degraded contaminated or wasted. A series of solutions may be implemented and are represented by avoidance and donation of edible fractions to social services or use to produce biofuels or biopolymers. A variety of (social and private) initiatves has evolved to use e.g. vegetables not ftting the standard, waste cooking or up-cycling of non-food waste.

SHORT DESCRIPTION

Food waste is made up of materials intended for human consumption that are subsequently discharged, lost, degraded or contaminated. The problem of food waste is currently on an increase, involving all sectors of waste management from collection to disposal; the identifying of sustainable solutions extends to all contributors to the food supply chains, agricultural and industrial sectors, as well as retailers and final consumers.

A series of solutions may be implemented in the appropriate management of food waste, and prioritised in a similar way to waste management hierarchy. The most sought-after solutions are represented by avoidance and donation of edible fractions to social services.

Food waste is also employed in industrial processes for the production of biofuels or biopolymers. Further steps foresee the recovery of nutrients and fixation of carbon by composting. Final and less desirable options are incineration and landfilling [2].

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DEVELOPMENT-DYNAMICS AND DRIVERS

Food wastage increases with increased food production. Also higher standards regarding quality of raw materials lead to sorting out of food not fitting the characteristics, e.g. curved cucumbers, too small potatoes.

Increasing awareness and environmental consciousness of people is leading to a movement of waste upcycling or re-use, not only regarding food, but also regarding all other materials. Initiatives not only come from consumers but also from retailers to promote unusual vegetables and increase consumer awareness to use or redistribute leftovers.

CONSEQUENCES ON FNS / SOCIETY

There are environmental repercussions, including all of the natural resources used and greenhouse gases emitted during the production or disposal of food that is not consumed. The FAO has developed a model to estimate the environmental footprint of food wastage, both food waste and food loss along the food supply chain, focusing on impacts on climate, water, land and biodiversity. The global volume of food wastage is estimated to be 1.6 Gtonnes of "primary product equivalents", while the total wastage for the edible part of food is 1.3 Gtonnes. This amount can be weighed against total agricultural production (for food and non-food uses), which is about 6 Gtonnes. [1]

Food wastage has huge environmental impacts and corresponding societal costs that need to be dealt with. The amount of food and material waste must be part of any effort aimed at meeting the sustainable development goals and in view of Food2030 sustainability and circularity.

CHALLENGES – NEEDS FOR R&I STRATEGIES

The amounts of food that cannot be used for counsumption are enormous, but the question remains when food becomes waste. Vegetables or fruit, that do not meet the standards and are thus difficult to process or sell may be processed by other, perhaps more time consuming methods. An inverted pyramid has been published as how to make use of food waste beginning with Source Reduction, Feed Hungry People, Feed Animals, to Industrial Uses and Composting only for the minority. Ways to prevent and divert food waste should be beneficial for the environment, society and the economy [4, 6].

The REFRESH project identified policy areas with the most promising opportunities in the following areas [7]:

- Waste and resource policy
- Hygiene and food safety
- Agriculture and rural development
- Fisheries Policies
- Unfair Trading Practices
- Bioenergy
- On-pack product information and date labelling
- Changing consumer behaviour
- Voluntary cooperation in the food chain

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7. POLICY AND OTHER TRENDS

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WOMEN'S EMPOWERMENT

CHALLENGE/TREND

Discrimination against women is still the most common form of social exclusion worldwide. Women encounter poorer educational opportunities than men, restricted access to certain fields of employment and barriers to holding political offices. Due to ongoing empowerment processes, women gain more power and control over their own lives and increasingly act as drivers of global transformations in areas such as education, poverty reduction, agriculture and urban development.

SHORT DESCRIPTION

Women and girls are still disadvantaged and discriminated in many aspects of the ecological, socio-cultural and political life. Empowering women means that women are gaining more power and control over their own lives, can exert influence within and outside the home, and promote social and economic change on the national and on the international level.

Empowered women can act as drivers for fundamental changes in areas such as education, poverty reduction, agriculture and urban development. They pass on their knowledge, experiences and mindset to their children, have a strong focus on health, family planning and the environment. They now run their own businesses and are part of the industrial workforce. Women's increased participation in the labour force and their contribution to the household income has a positive influence on children's nutrition, health and educational prospects.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Compared to men, women are considered disadvantaged and discriminated in many aspects of the economic, socio-cultural and political life (e.g. access to educational opportunities and certain fields of employment as well as political offices and mandates) in large parts of the world. [1]

Women need to be empowered to narrow the gender gap to reach gender equality and to be able to act as accelerators and pioneers of transformation in many areas relevant to society. Gender equality and women's empowerment is an important development priority, as highlighted by its inclusion in the Sustainable Development Goals (SDG 5: Achieve gender equality and empower all women and girls). [2]

Empowerment is a multi-dimensional social process that helps people gain control over their own lives. Consequently, empowering women means that they can foster their power for use in their own lives and communities for issues that are important to them. Empowered women can make their own choices and have access to opportunities and resources that allow them to follow options of their own interest. They can influence their own life in public and private spheres, and promote social and economic change on the national and international level. [3]

CONSEQUENCES ON FNS / SOCIETY

Currently, it can be observed that ongoing empowerment of women has already improved women's lives substantially in many areas of life, especially in developing countries. Women seem to have managed to better take advantage of reduced trade barriers and technological change resulting from globalisation than men. Consequently, more and more women run their own business and are part of the industrial and service-oriented workforce. Globally, nearly half of all agricultural workers are women, as women have increasingly got the possibility to cultivate their own farmland. In addition, the number of women attending tertiary education has increased by more than seven times since 1970; now more than half of all students are women. Even though women's salaries often lag behind those of men, women's income provides to them financial independence, autonomy, and access to information, better education and extended networks. [1]

Because of their engagement for their own rights, women also act regularly as drivers for fundamental changes in areas such as education, poverty reduction, agriculture and urban development. They pass on their knowledge, experiences and mindset to their children, have a strong focus on health, family planning and the environment. Women's increased participation in the labour force and their income influences children's nutrition, health and educational prospects positively. They take out micro-loans and invest in small businesses and join in networks and cooperatives or invest in their communities to create an economically, socially and environmentally sustainable foundation for their progress. [1]

CHALLENGES – NEEDS FOR R&I STRATEGIES

Women's empowerment can open many doors for women to contribute to actively shaping society now and in the future. This is particularly true for developing and emerging countries. Research should therefore focus on the ongoing changes in societies that can be attributed to the new status of women. It should investigate the interactions of these changes with current global technological, economic and cultural trends and derive lessons learned for innovation management. The overall impact of the ongoing changes in gender relations on the world society needs to be researched as well. [1]

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

RESPONSIBLE RESEARCH AND INNOVATION (RRI)

CHALLENGE/TREND

Responsible research and innovation anticipates and assesses potential implications and societal expectations with the aim to foster the design of inclusive and sustainable research and innovation. RRI often includes open science which aims at making scientific research accessible to all.

SHORT DESCRIPTION

Responsible Research and Innovation (RRI) implies that societal actors (researchers, citizens, policy makers, business, NGOs, etc.) work together during the entire research and innovation process to better align both the process and its outcomes with the values, needs and expectations of society [1].

RRI thus asks the crucial question: What kind of innovations and what kind of economy or society do we want? And who is the 'we'? [2].

In practice, RRI is implemented as a package that includes **multi-actor and public engagement** in research and innovation, enabling easier access to scientific results, the uptake of gender and ethics in research and innovation content and process, and science education.

Closely linked to RRI is the concept of Open Science (OSc). OSc aims at making scientific research, data and dissemination accessible to other scientist and all levels of society to better facilitate collaboration. It encompasses all sorts of practices to make sharing and communicating science knowledge easier.

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DEVELOPMENT-DYNAMICS AND DRIVERS

Responsible Research and Innovation (RRI) has recently emerged as a new framework for science and technology governance addressing the limited attention to societal impact, and little or no active involvement of civil society in the R&I process. The concept articulates the need for mutual exchange by which societal actors become responsive to each other early-on in the process of innovation, with a view to facilitate ethically acceptable and sustainable innovation [3].

RRI has emerged at the EU level [1] about the need for science with society and emphasizes the institutionalization of **inclusive and reflexive deliberation** in the setting of research trajectories (e.g. in H2020). In the context of food and nutrition security, open science entails the development and implementation of cloud-based data infrastructures to allow different stakeholder to benefit from the 'big data revolution' in a responsible way. OSc is thus often included as critical component of RRI.

CONSEQUENCES ON FNS / SOCIETY

By adopting RRI/Osc approaches more rapid progress is expected to be made towards the solution of grand societal challenges such as food and nutrition security (FNS). Realizing an integrated and holistic food system approach implies the involvement of a wide variety of stakeholders and experts in the research and innovation (decision-making) process. Practicing a more responsible R&I requires R&I processes to become

- **diverse and inclusive**: involve early a wide range of actors that engage in R&I practice, deliberation, decision-making to yield more useful knowledge)
- **anticipative & reflective**: envision impacts and reflect on the underlying assumptions, values and purpose better understand how R&I shapes the future
- **Open and transparent:** communication in meaningful way through methods, results, an impaction to enable public scrutiny and dialogue.
- **Responsive and adaptive to change:** be able to modify modes of thought and behaviour, and adapt overarching structures to changing circumstances, knowledge, and perspectives.

RRI calls for specific attention is being paid in R&I activities to public engagement, gender equality, ethics science education and open access.

CHALLENGES – NEEDS FOR R&I STRATEGIES

Engaging society for responsible research and innovation is not an easy task. RRI is an uncertain and somewhat unpredictable process that is value-based, and thus allows for controversial debate of purposes and values in FNS. RRI suggests that some innovations will be selected over others, namely the 'responsible' ones. This is hard work in any kind of setting, particularly so when it is unclear as to exactly what a 'responsible innovation' is and who will be the one to determine this. It poses tough questions [2] at

- micro-level (e.g. for researchers: what to do in the context of a RRI project?)
- meso-level (e.g. for research funders: what kind of projects to select and reward?), and
- macro-level (e.g. for policy-makers: what types of research should we prioritize?)

Though new options to move forward are being explored and pushed (H2020, national initiatives), there remains a gap between RRI and how research funding in the area of food and health conceives of innovation [3]: Innovation in the food and health domain is perceived to be focused on biosciences and marketable applications to the neglect of social sciences and broader public interest; that the "innovation network" is primarily viewed as centered around scientific/technical and industrial actors; and that the demand-pull dynamic – where the 'need' remains predominantly associated with the market - is relevant to innovation in the area of food and health.

There are also significant obstacles at both national and organisational levels to **mainstreaming** Responsible Research and Innovation (RRI). These relate to priorities and incentive schemes, but also simply to the lack of adequate measures of and for responsibility in food research and innovation.

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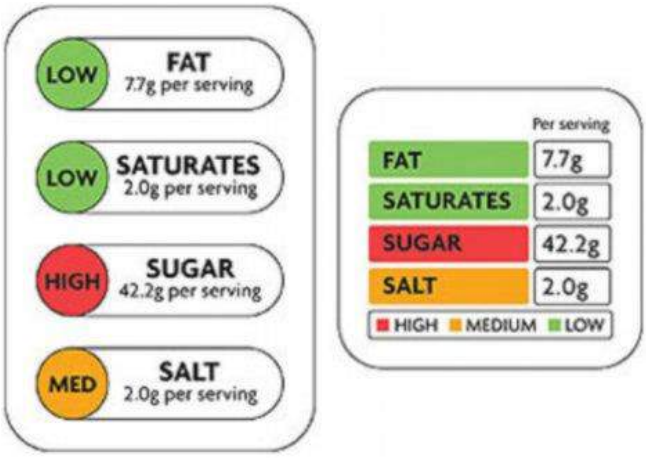
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774088

FOOD REGULATION

DRIVER/TREND



Alcohol, tobacco and nutrition containing high amounts of sugar, salt and fat and are considered as being among the highest risk factors for non-communicable diseases (NCDs). Over-consumption of sugar is a major cause for obesity, diabetes and several other NCDs. Several recommendations from WHO and lately also regulations in single countries are addressing these risk factors.

SHORT DESCRIPTION

With regard to alcohol and tobacco, recent policies are starting to target these products, especially the marketing of them among children and young adults. The WHO recommended a ban of alcohol and tobacco advertisement in media, including social media, billboards, etc. and especially those advertisements designed for young consumers [2]. Furthermore, the WHO sees no added value in the intake of sugar and recommends to reduce the consumption of free sugars to less than 10% of a person's daily energy intake (equivalent to around 12 teaspoons of table sugar for adults, incl. free sugars like honeys, saccharide).

However, medical societies and health alliances warn also that children and adults currently eat too much free sugars, fat and salt and this overconsumption is a key driver of overweight and obesity, as well as other diseases. [1]

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DEVELOPMENT-DYNAMICS AND DRIVERS

WHO Euro Region adopted a Framework for Alcohol Policy for the Region. This has 5 ethical principles which include "All children and adolescents have the right to grow up in an environment protected from the negative consequences of alcohol consumption and, to the extent possible, from the promotion of alcoholic beverages". [2]

Information rather than regulation could play an important role to reduce sugar, salt and fat consumption [6]. Several attempts have been made in the past to introduce a mandatory labelling system for processed and packaged food that informs about the intake of sugar, salt and fat. Designed as a traffic light in the colours red, green yellow the amounts relate to the daily consumption recommendations of the WHO or the official recommendations of the UK Food Standards Agency.

France's ministers for health, agriculture and the economy signed a decree in October 2017 introducing a voluntary labelling scheme for food products to reduce obesity. Following the UK's 'traffic light' system, France has opted for its own food score system. The 'Nutri score' gives a rating to any food (except single-ingredient foods and water) going from a dark green A (best) to a red E (worst), by weighing the prevalence of bad and good nutrients. The initiative seeks to give consumers comprehensible information so that nutritional values are taken into account as much as price or taste when food shopping, ministers announced.

In many countries there is an ongoing public debate on banning sugar-added drinks from school environments and canteens, the promotion of healthy diets for schoolchildren, the limitation of commercials for sugar added drink in TV programmes for children (incl. social media) and product placements in children's programmes. A number of scientific associations, institutions and authorities have issued policy recommendations that ultimately aim to reduce intake of sugars, with a special focus on recommendations for children. These policy recommendations can be generally categorised in actions that i) tackle provision of information to the consumers, e.g. labelling of sugar content in foods, restrictions of marketing practices for foods high in sugars content, encouraging healthy behaviours such as drinking water, ii) making the healthy option available by improving the 'food environment', e.g. offering freely available water and limiting the availability of foods and beverages high in sugars content in schools or public environments, reformulating processed foods to reduce sugars content, and iii) implementing financial (dis)incentives such as taxes on products with high sugars content to dissuade consumers from purchasing or consuming them [6].

CONSEQUENCES ON FNS / SOCIETY

According to the OECD, colour-coded labelling schemes can reduce caloric intake by 4% and nudge 18% of people to pick a healthier option. [5]

Another approach could be to introduce taxation of sugary drinks. Studies on such pilot policies have shown "that a tax of 20% on sugary drinks can lead to a reduction in consumption of around 20%, thus possibly limiting obesity and diabetes" [3]. This intervention might help to reduce health care costs in the long run, as the example of Mexico already suggests. [4]

CHALLENGES – NEEDS FOR R&I STRATEGIES

Conditional recommendations are made when there is less certainty about the balance between the benefits and harms or disadvantages of implementing a recommendation. This means that policy-making will require substantial debate and involvement of various stakeholders for translating them into action. [6]

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