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EUROPE INNOVA
Sectoral Innovation Watch

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Food and Drinks Sector

Final Sector Report

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M. Leis
G. Gijsbers
F. van der Zee

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Europe INNOVA Sectoral Innovation Watch

Detailed insights into sectoral innovation performance are essential for the development of effective innovation policy at regional, national and European levels. A fundamental question is to what extent and why innovation performance differs across sectors. The second SIW project phase (2008-2010) aims to provide policy-makers and innovation professionals with a better understanding of current sectoral innovation dynamics across Europe

SIW Coordination: TNO	
Carlos Montalvo (carlos.montalvo@tno.nl)	Annelieke van der Giessen (annelieke.vandergiessen@tno.nl)

Central to the work of the Sectoral Innovation Watch is **analysing trends in, and reporting on, innovation performance in nine sectors** (Task 1). For each of the nine sectors, the focus will be on identifying the innovative agents, innovation performance, necessary skills for innovation, and the relationship between innovation, labour productivity and skills availability.

Sector Innovation Performance: Carlos Montalvo (TNO)	
Automotive: Michael Ploder (Joanneum Research)	Knowledge Intensive Business Services: Christiane Hipp (BTU-Cottbus)
Biotechnology: Christien Enzing (Technopolis)	Space and Aeronautics: Annelieke van der Giessen (TNO)
Construction: Hannes Toivanen (VTT)	Textiles: Bernhard Dachs (AIT)
Electrical and Optical Equipment: Tijs van den Broek (TNO)	Wholesale and Retail Trade: Luis Rubalcaba (Alcala) / Hans Schaffers (Dialogic)
Food and Drinks: Govert Gijsbers (TNO)	

The **foresight of sectoral innovation challenges and opportunities** (Task 2) aims at identifying markets and technologies that may have a disruptive effect in the nine sectors in the future, as well as extracting challenges and implications for European companies and public policy.

Sector Innovation Foresight: Matthias Weber (Austrian Institute of Technology)	
Automotive: Karl Heinz Leitner (AIT)	Knowledge Intensive Business Services: Bernhard Dachs (AIT)
Biotechnology: Govert Gijsbers (TNO)	Space and Aeronautics: Felix Brandes (TNO)
Construction: Doris Schartinger (AIT)	Textiles: Georg Zahradnik (AIT)
Electrical and Optical Equipment: Tijs van den Broek (TNO)	Wholesale and Retail Trade: Susanne Giesecke (AIT)
Food and Drinks: Govert Gijsbers (TNO)	

Task 3 will **identify and analyse current and potential bottlenecks that influence sectoral innovation performance, paying special attention to the role of markets and regulations.** Specifically, the analysis will cover the importance of the different factors in the propensity of firms to innovate.

Role of markets and policy/regulation on sectoral patterns of innovation: Carlos Montalvo (TNO)	
Katrin Pihor (PRAXIS)	Klemen Koman (IER)

Task 4 concerns **five horizontal, cross-cutting, themes related to innovation**. The analyses of these horizontal themes will be fed by the insights from the sectoral innovation studies performed in the previous tasks. The **horizontal reports will also be used for organising five thematic panels** (Task 5). The purpose of these panels is to provide the Commission services with feedback on current and proposed policy initiatives.

Horizontal reports	
National specialisation and innovation performance	Fabio Montobbio (KITes) and Kay Mitusch (KIT-IWW)
Organisational innovation in services	Luis Rubalcaba (Alcala) and Christiane Hipp (BTU-Cottbus)
Emerging lead markets	Bernhard Dachs (AIT) and Hannes Toivanen (VTT)
Potential of eco-innovation	Carlos Montalvo and Fernando Diaz Lopez (TNO)
High-growth companies	Kay Mitusch (KIT-IWW)

Contents

Acknowledgements

The final sector report for the food and drinks sector builds on results of the various tasks in the Europe INNOVA Sectoral Innovation Watch:

Leis, M. (2010) *Sectoral Innovation Performance in the Food and Drinks Sector*, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, March 2010

Leis, M., G. Gijsbers and F. van der Zee (2010) *Sectoral Innovation Foresight – Food and Drinks Sector*, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Montalvo, C., M. Mayer and F. van der Zee (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Food and Drinks Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

H. Grupp[†], D. Fornahl, C.A.Tran, J. Stohr, T. Schubert, F. Malerba, Montobbio F., L. Cusmano, E. Bacchiocchi, F. Puzone, (2010) *National Specialisation and Innovation Performance*, Final Report Task 4 Horizontal Report 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, March 2010

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Dachs, B., I. Wanzenböck, M. Weber, J. Hyvönen and H. Toivanen (2011) *Lead Markets*, Final Report Task 4, Horizontal Report 3, for DG Enterprise and Industry, European Commission, March 2011

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Executive Summary

The food and drinks manufacturing industry is a diverse and complex sector. There are ample possibilities for performance improvement and innovation in the food and drinks industry as well as a variety of challenges ranging from a lack of financial and human resources, fragmented consumer interests and concerns to the implementation of various, and new, regulations related to health, the environment, labour conditions, etc. The sector is caught between novelty and tradition. In contrast to all other products, foods and drinks are ingested, healthy or unhealthy, from infants to old age, which calls for rather unique requirements for safety and health. But also other dimensions like taste, consistency, olfactory properties play a role along with ethical, religious and psychosocial aspects.

The food and drinks manufacturing industry has strong links with down- and upstream sectors like agriculture, life sciences, packaging, logistics and retail, which also from an innovation perspective do play an important role. Although food and drinks are essential for human life and have a large influence on human health and wellbeing, the industrial sector of food and drinks manufacturing is generally defined as mid-to-low tech in the literature (e.g. Hirsch-Kreinsen, 2006; Kirner et al., 2009), an observation that is also backed by the CIS4 data analysis conducted in the frame of this project.

The product palette from the food and drinks manufacturing industry ranges from niche and traditional specialty products to highly innovative and modified ones like convenience and functional foods and drinks. Also the customer preferences for foods and drinks spans a very wide spectrum that ranges from fast food to slow food, from vegan to meat specialties, and from innovative "organic" drinks to the latest alcoholic cocktail innovations. In general, there is a clear distinction between innovative food and drinks companies and traditional ones that put much emphasis on continuity rather than on innovation and change (CIAA, 2006a). This seeming dichotomy is especially apparent in the food industry which is characterised by highly innovative and research-intensive activities (e.g. functional and novel foods) on the one hand and many traditional manufacturing methods and products that in some cases are not even allowed to be changed if wanting to keep certain labels and names (e.g. the German "Reinheitsgebot", or broader, the EU's Protected Geographical Status (PGS) framework).

Key statistics and innovation

- 78% of all EU-27 food and drinks manufacturing firms have less than 10 persons employed. Together they generate 6.95% of the sector's turnover.
- These micro-companies are not included in CIS4 statistics and therefore – due to lack of data - also not analysed within this study.
- 17% of all firms are medium-sized companies with 10 to 49 persons employed; altogether 95.5% of all EU-27 food and drinks manufacturing companies have less than 50 employees.
- Only 0.86% of all firms are large companies with 250 or more people employed; together they generate 51.54% of the sector's turnover.

On the taxonomy of Pavitt (1984), the food and drinks industry is categorized as 'scale intensive' or 'supplier dominated' with firms depending on suppliers of equipment and others for imitation and technology transfer (Europe INNOVA, 2008). The Community Innovation Survey results provide a first impression of the innovation performance of the food and drinks manufacturing industry, and suggest that its performance is by and large in line with the CORE NACE manufacturing average, some indicators scoring below average and others scoring better than average. Especially low is the use of patents as well as the share of turnover from new-to-market products. On the other side, the sector makes much more use of trademarks and design registrations. The low share of patents can also stem from the general difficulty to get patents approved for food and drinks products that are often based on recipes.

In regard to the CIS4 innovation indicators, large firms show the highest scores, especially when it comes to introducing new products to the market. However, medium-seized as well as small sized-companies seem to perform quite well when it comes to introducing new products to their firm, which, however already exist in a similar way on the market. This could hint towards a specific strategy of small(er) firms to look at successful products and try to introduce similar ones themselves (similar to generic brand strategies). Also small firms show a comparatively high degree on cooperation with national markets and are being well funded by local and regional authorities for innovation activities. Small firms also show the highest R&D intensity, defined as total R&D expenditure divided by total turnover. The collaboration with universities and research institutes, especially international ones seems to be very difficult for small companies and is almost only be done by large firms.

Carriers of innovation – human resources, skills and competences

The skills profile within the food and drinks manufacturing industry seems to look twofold. On the one hand, many activities within this sector are classified as “elementary occupations” necessitating only lower level skills, whereas on the other hand, highly specialized or interdisciplinary scientific personnel is required, especially for innovation activities. Scientific advances as well as new regulations also cause changes for qualification profiles or even lead to new job categories. Higher demand in regard to hygiene and standards also call for new training and skills updates for persons working in elementary occupations.

Many European food and drinks manufacturing industries, especially larger food companies are experiencing a shortage in high-skilled workers, especially food scientists, food technologists and food engineers, which is seen as a great hampering factor for innovation. In general, the food and drinks industry, especially large companies, seem to have difficulties in finding qualified personnel, particularly in research, development and food science. This may also be due to the image of the sector as rather low-tech with low wages. What is perceived by the industry itself is a lack of food engineers and researchers and there seems to be a general need to further develop industry specific skills. The food and drinks industry thinks that it is relevant to promote the interest in food-specific scientific qualifications in the early stages of education (cf. HLG, 2008:10).

The share of employees with higher education was lower in food and drinks manufacturing than the manufacturing average. According to the Europe INNOVA report from 2008, the share of employees with higher education in the food, drinks and tobacco manufacturing sector was with a 6.6% share almost half of the manufacturing average with a 13.7% share. However, these findings could not be assessed within this report due to lacking (Eurostat) data about the education levels by NACE sector.

In 2005 52% of all EU25 food, drinks and tobacco enterprises made use of company training, a share that is below the manufacturing average. The findings also show that especially SMEs and small companies show a lack in e-skills among the employees and only 50% of large companies reported practicing regular ICT training. Company size and costs are named as the main barriers to ICT implementations

A variety of programmes have been initiated, especially in the UK, to improve the skill availability and competitiveness of the food and drinks manufacturing industry. Many of these also deal with rather basic issues like hygiene, e.g. mandatory training programmes in HACCP - Hazard Analysis and Critical Control Points practices.

The food industry is currently also a major growth sector for the robotics industry (World Robotics, 2008). As robots are becoming more “intelligent”, especially in regard to pattern recognition, more sensitive (being able to handle fragile objects and being fitted with improved sensors) and cheaper, the growth is likely to continue. Some latest developments include a deboning robot for the meat processing industry which already yields higher results than achieved by skilled workers.

Sector innovation futures

The picture of the food and drinks industry is a mixed one; a similar observation applies to consumer preferences and choices which from natural and minimally processed foods and drinks over specialised and fortified and high-tech nutrition to a diversity of convenience and fast foods. Many different factors such as economic prosperity, ecological consciousness, environmental problems, food safety concerns, importance of health, technological progress, acceptance of new technology and economic prosperity can have an influence on the direction of consumer and industry choices.

Five different scenarios have been developed to depict different trajectories for the food and drinks manufacturing industry to develop in the future. The future reality is likely to be a mixture of the different elements sketched in the different scenarios, with each of the scenarios giving a plausible look into the future, based on current and emerging societal, economic and technological developments.

1. Business as usual

Business as usual (BAU) is the reference scenario that depicts the current diversity and huge differences in the food and drinks industry ranging from highly fortified and functional food over the trend of natural and organic products to fast food and food with no considerable nutritional value or even harmful ingredients. This scenario does not score high on overall innovativeness, although some sectors (e.g. functional food) will have great potential while others more or less continue their way of only small and incremental improvements in the future. Within society larger gaps may develop between healthy and unhealthy eaters which will also be reflected in individual health. The BAU scenario acts as reference scenario; the four other scenarios each depict a situation in which at least one of the described elements will become more prominent.

2. Going natural

This scenario depicts a growing emphasis on natural foods products, i.e. food perceived as natural by consumers, and less towards food processing. Many innovation potentials like the utilisation of genetically modified organisms (GMO) or nanoparticles in food production as well as other high-tech experiments are generally not popular with the consumer. But also conventional “fast food” that is considered unhealthy will be more and more replaced by other fast alternatives such as salads or fruit. Here, innovations mainly lie in finding ways to process food with healthier ingredients (e.g. natural food additives) or improved testing and process automation. A growing consumer concern over the environment and ethics (e.g. animal rights, fair trade etc.) are driving factors. This scenario is more likely under the condition of higher economic prosperity and greater concern over health issues. But “*Going natural”* can also become more likely if the perception of ‘’industrial food’’ and industrial food producers becomes more negative. This can for example be due to food scandals or the uncovering of relations between certain ingredients commonly used in processed food and health risks (e.g. cancer, obesity etc.).

3. Cheap and convenient

This scenario reflects a setting where the general prosperity as well as interest in health, future and innovation is declining. Contradicting information about nutritional health benefits as well as scientific fraud combined with higher budget consciousness leads to a growing disinterest of consumers in healthy nutrition. Budget (for some involuntarily), fastness, convenience and indulgence are major drivers. Resources for innovation are rather scarce and companies are mostly interested in cost reduction. In extreme cases this could lead to very problematic implications for health and the environment. “Cheap and convenient” may become a growing trend for low income groups and people who lack sufficient knowledge about nutrition or time for adequate food preparation. Major problems associated with this scenario are obesity and environmental problems.

4. High-tech nutrition

In this scenario technological progress is fast and developments from different disciplines from biotechnology to material science are influencing innovations in food and drinks manufacturing. Consumers tend to increasingly accept novel technologies in the area of food and drinks. Health improvement beyond just healthy nutrition stands in the centre of interest, which is considered to be achievable only through advanced technological modifications of food and drinks products that even result in medicinal food. This scenario requires economic prosperity as well as high interest in novel technologies. It also bears the potential danger of being too optimistic and thus overlooking potential negative side effects and may face challenges if problems may occur.

5. Emergency

This scenario depicts a situation where some of the basic requirements of food security (availability and accessibility) are in jeopardy and where the main goal for solutions and innovations lies in getting enough food. The "emergency" scenario is certainly a kind of worst case scenario, but if sustainability will be neglected, this could become a realistic outcome. Current trends in desertification and reliance on monocultures in large scale agriculture already seem to point towards this direction and in many countries around the world the situation for food security and safe drinking water is already bad and still worsening. Strong global population growth and higher incomes, especially from a large rising middle-class in emerging economies (e.g. BRICs) will add to the "Emergency" scenario.

Future innovation possibilities

Huge technological and innovation possibilities in food and drinks manufacturing face the cautiousness and risk-aversity of consumers. One of the crucial questions for innovation, and especially for technological product innovations, is typically related to consumer acceptance. What factors determine whether or not an innovation will be successful with customers? Current innovation trajectories include:

- Utilisation of natural ingredients for preservation and with anti-microbial properties
- Reduction in fat, salt, sugar and artificial preservatives and processing ingredients without compromising taste and texture
- New functional foods, e.g. with mood improving and performance-enhancing effects
- New preservation methods (e.g. membrane filtering, high pressure, enzymes and especially other non-thermal methods).

Innovations from other sectors are very important for the food and drinks industry, e.g.:

- Smart labels
- Improved packaging materials
- Faster and better food testing methods
- Eco-friendly production
- Innovations in logistics and transport.

The future may witness totally new forms of production and products, such as cultured/in-vitro meat, personalized nutrition, functional food based on nutrigenomic, epigenetic and neurological research as well as medicinal food, "customizable food" and perhaps even food replacement products.

Barriers to innovation

In general, it can be said that the possibilities for the food and drinks manufacturing industry are great from a solely technological or "engineering" point of view. Many inputs for innovations can also come from biotechnology, nanosciences and medicine, but not all possible innovations may also be acceptable in regard to risk assessment, regulations and consumer preferences. But can these possibilities be realized and how will they be perceived by regulators and consumers?

Unlike it is the case in other sectors like automotive, aerospace, ICT and biotechnology, for example, technological innovation does not necessary relate with economic success within the food and drinks manufacturing sector. Some innovative ideas such a personalised nutrition or the substitution of less healthy ingredients through healthier ones (including a reduction in fat, salt, sugar etc.) without negatively impacting properties like taste and texture require substantial technological know how and may be challenging to achieve.

Other innovations such as functional or even medicinal food need to conform with strict laws and regulations making their development even more expensive and introducing an element of future uncertainty about their approval and marketing success which can cause some firms to refrain from investing in such developments.

Other technologies, like GMO, nanotechnology and certain “high tech” or “synthesized” ingredients are not accepted within foods and drinks by many consumers and are subject to strict regulations or regulatory uncertainties. On the other hand, some food and drinks products that are being manufactured in traditional ways and without (significant) changes sometimes over centuries are much valued by customers and generate high economic profits.

Some main barriers that have been identified are scientific and technological challenges, uncertainty about consumer interests, laws and regulations as well as financial constraints and lack of qualified human resources. However, regulations as such (e.g. in regard to food safety, hygiene etc.) are generally viewed as positive for innovation as long as the same conditions apply in the same way for all competitors.

Horizontal issues

National specialisation

National specialisation is well reflected within national clusters that specialise on a specific industry or benefit from the proximity of different firms, e.g. in regard to collaboration and a shared infrastructure. A national economy is composed of different sectors with specific patterns of innovation. National specialization is defined as the weight of the sector in a country, relatively to the weight of the same sector in the world and evaluates the distribution of the sectoral activities of that country relatively to the rest of the world. National specialization patterns are driven on the one hand by the economic dynamics of the different sectors; on the other hand, they depend upon the specific innovative activities of the companies. In general the food and drinks sector can be considered as a traditional industry. Technologies that relate to food processing and agricultural machinery and apparatus actually do not count as food and drinks manufacturing and hence are not considered here in regard to national specialisation.

Most of the EU 15 countries have gained comparative and technological advantages in the food and drinks sector. Especially, Denmark is highly specialized in this sector and can be seen as the technology leader in food and drinks. Denmark is also an example of consistent good combination of technological specialisation as well as "high quality" of specialisation, particularly in the fields of biotechnology and food and drinks.

However, within the food and drinks sector, greater technological specialization does not correspond to greater innovativeness of the countries. For example, Spain is strongly specialized in this sector, but it ranks average or even below in the success indicators for innovation. This is likely due to the fact that innovations in this sector are typically less knowledge- and technology-intensive than in other more R&D-oriented sectors and traditional regional specialities can be economically very successful.

Clusters

The European Cluster Observatory identifies 148 food and drinks clusters, with different degrees of innovativeness. The highest number of innovative clusters can be found in Germany, France, the UK and Belgium, Unfortunately Germany, the UK and Belgium are not included in the CIS4 micro database. Interdisciplinarity seems to become increasingly important for (food and drinks) clusters and could be an important subject for (future) cluster policy.

Clusters are engaged in a balancing act between co-operation and competition which has to be maintained to spur innovation and competitiveness. It might be necessary that future clusters go beyond the traditional industry-lines and research areas – something that may at first sound counterintuitive when thinking about industrial clusters – to enable more interdisciplinarity and provide complementary competences.

Eco-innovation

Especially agriculture and animal farming contribute negatively in regard to energy consumption, carbon dioxide / greenhouse gas emissions and water pollution. Also transport contributes its share, as the growing consumer concern over so-called food miles is also reflecting. But the food miles issue also relates to consumer choices, i.e. if consumers prefer to buy local products and are considerate about food miles or if they nonetheless prefer to buy products that got imported from afar. If taking bottles water, as an example, which is quite popular with consumers (including health oriented ones), which, however, has significant negative environmental impacts including energy consumption for processing, cooling, transport and bottling, health risks and environmental pollution (related to the bottles) and problems in regard to ground water and water availability (National Geographic, 2010) . Some policy-makers, e.g. in the US, have already reacted and banned the sales of bottled water in local supermarkets.

The reduction of food waste and wasted food, energy efficiency in manufacturing and especially improved water usage belong to the major challenges for the food and drinks manufacturing industry in regard to ecological improvement. Solutions range from utilising food waste as energy source over the introduction of labels that indicate the amount of renewable energy for production and the ecological footprint of the products to laws, regulations and changing consumer behaviour (e.g. in avoiding food going to waste).

Sectoral policy innovation

The report concludes with addressing some of the major policy related issues which include strategies for healthier nutrition, reduction of energy consumption and environmental improvements throughout the sector and the value chain, ethical considerations (including animal concerns and fair trade), food affordability and the support for SMEs and innovation activities.

1 Patterns and performance of sectoral innovation

Food and drinks are essential for human life and a major co-determinant of human health and well-being. In the production and consumption of food and drinks various dimensions play a role, including safety, health, texture, looks, caloric value, taste and olfactory properties. Food consumption is influenced by social, cultural and religious values, norms and beliefs.

The food and drinks sector accounted for 942 billion euro of turnover, 197 billion euro of value added and 4.700 thousand jobs in the EU-27 (data 2006, see Eurostat 2009). With 13% of employment and 13% of turnover in total EU manufacturing, it is one of the major European manufacturing industries. The economic and innovation performance of food and drinks manufacturing, however, should be seen in close relation to and dependent on the performance of other parts of the food and drinks value chain which includes agriculture, biotechnology (for food testing, safety, ingredients, and nutritional research), material sciences (for packaging), ICT (for transport and logistics), wholesale and retail trade, and food services (catering, bars, canteens and restaurants).

The food and drinks manufacturing sector is generally defined as a mid-to-low tech industry (e.g. Hirsch-Kreinsen 2006), an observation that is supported by recent empirical evidence based on CIS4 data (this project).

Despite low scores on standard innovation indicators (CIS4), the innovation opportunities for the food and drinks industry are manifold. Areas, such as new product development, new technology, new processing methods, new formulations and novelties in packaging and merchandising, are under constant review, especially at large companies. But not all innovation ideas actually make it into successful innovations. Some are difficult to implement in regard to regulations (e.g. medicinal functional foods, the use of nano-sized particles as food ingredients and genetically modified ingredients), others may turn out not be popular with customers (e.g. potential trade-offs between low-fat foods and taste) or may be too expensive to develop (e.g. whole new processing methods for improving the healthiness of products or reducing energy consumption during processing). Regulation may act also as a driver of innovation, for example, research into natural preservatives in order to reduce the consumption of certain ‘artificial’ ingredients.

1.1 Statistical definition of the sector and sector-specific indicators

Eurostat statistics define the “manufacturing of food products and drinks” as a distinct major industrial activity. In the new NACE Rev 2 classification introduced as from January 2008, the manufacture of food products and the manufacture of drinks are treated as two separate industrial activities (two-digit level). Under NACE Rev 1.1 food and drinks was treated as one sector (NACE 15).

The manufacture of food products covers a number of production, processing and preservation activities adding further value to primary agricultural and fishery inputs, and intended for intermediate or final human or animal consumption. The classification is mainly based on a sub-sectoral distinction between various product groups: meat, fish, fruit and vegetables, fats and oils, dairy products, grain mill products, bakery products, as well as certain animal feeds and other food products including bread and biscuits, sugar, various pastas, cocoa, coffee and tea.

The manufacture of drinks includes the manufacturing of non-alcoholic drinks and mineral waters, of beer, cider and wines, and the manufacture of distilled alcoholic drinks. However, milk-based drinks, fruit and vegetable juices as well as coffee, tea and mate products are listed under 'manufacture of food products'. In statistical terms, products have been categorized along the line of basis material being used (e.g. fish, meat or vegetables), but not in regard to function (e.g. functional food, nutraceuticals), novelty (e.g. novel foods, convenience foods etc.) or production method (e.g. organic, genetically modified, synthesized etc.).

Table 1.1 Statistical classification of activities in the food and drinks industry

NACE 1.1	**NACE 2 (new)**
DA Manufacture of food products; drinks and tobacco	C Manufacturing
15 Manufacture of food products and drinks	**10 Manufacture of food products**
15.1 Production, processing and preserving of meat and meat products	10.1 Processing and preserving of meat and production of meat products
15.2 Processing and preserving of fish and fish products	10.2 Processing and preserving of fish, crustaceans and molluscs
15.3 Processing and preserving of fruit and vegetables	10.3 Processing and preserving of fruit and vegetables
15.4 Manufacture of vegetable and animal oils and fats	10.4 Manufacture of vegetable and animal oils and fats
15.5 Manufacture of dairy products	10.5 Manufacture of dairy products
15.6 Manufacture of grain mill products, starches and starch products	10.6 Manufacture of grain mill products, starches and starch products
	10.7 Manufacture of bakery and farinaceous products
15.8 Manufacture of other food products	10.8 Manufacture of other food products
15.7 Manufacture of prepared animal feeds	10.9 Manufacture of prepared animal feeds
15.9 Manufacture of drinks	**11 Manufacture of drinks**
	11.0 Manufacture of drinks

Not included in food and drinks is the preparation of meals for immediate consumption, such as in restaurants and catering services. Other supplying industries like agriculture, fisheries, biotech and chemicals (food ingredients), packaging, producers of machinery and food testing activities as well as transport, logistics, retail, distribution and catering of food and drinks products are also not included; all relate to other NACE codes.

1.2 Characterisation of innovation in the food and drinks sector

Innovation is food and drinks is challenging, as many dimensions such as safety, taste, trust, price, identity, culture and habits have to be taken into account and to be met, leading to an often a delicate balancing between innovativeness and precaution. Consumer trust plays a key role.

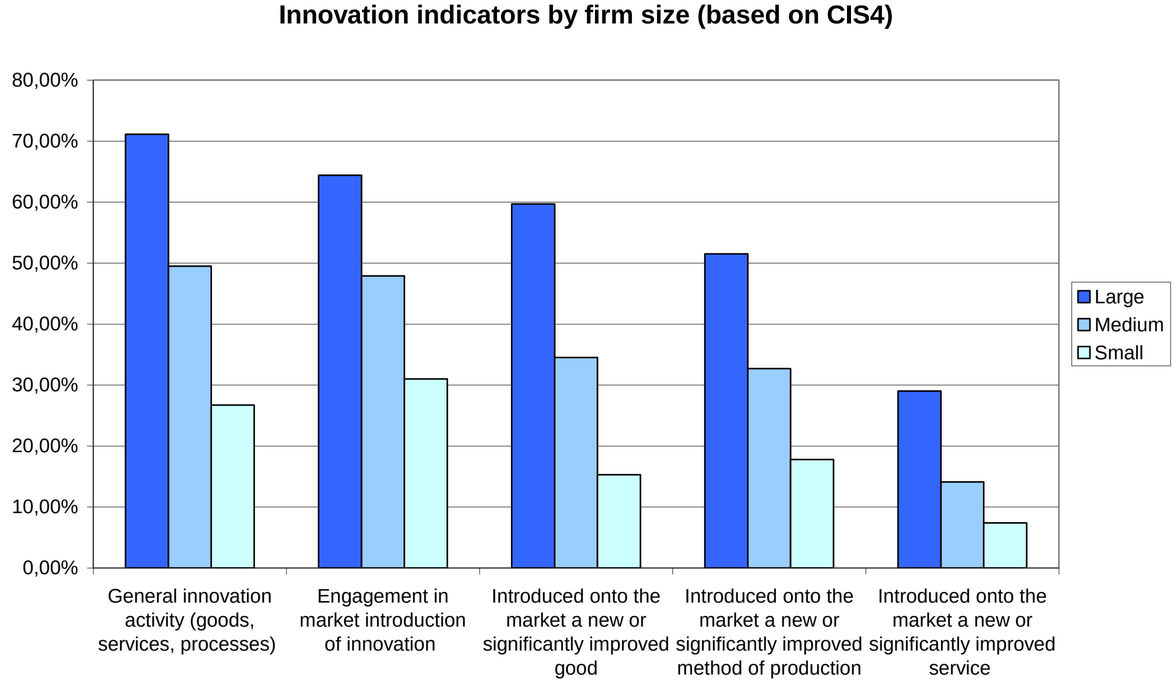
Moreover, in many respects the food and drinks manufacturing industry appears to follow a different logic than manufacturers of electronics, machinery, automobiles or other high-tech durables which also affects the mode, logic and strategy of innovation and successfulness. Whereas especially in ICT and automobiles old models are easily recognised as outdated and out-of-fashion and loose in value (except for collector's items), traditional and unchanged food and drinks recipes and tastes are and remain to be valued by many customers. Especially small companies often produce and sell traditional foods or focus on continuation and even build their reputation upon this. Also certain regulations such as the German "Reinheitsgebot" actually hinder innovations being introduced in order not to alter traditional and established products such as beer or sausage that are often valued by the customer.

In food and drinks new products are often not introduced as replacements but as additions and sold alongside well-established articles (e.g. classic coca cola next to coca cola light and zero coke). Other articles are explicitly advertised as "original products" following strict and sometimes century-old rules of production (e.g. "Original Parma Ham"), which on first glance seems to contradict innovativeness. In food and drinks, dimensions like 'faster, smaller, stronger' are not necessarily benchmarks for innovativeness – often to the contrary - and it even might become questionable how much (technological) innovation is actually desired in foods and drinks by customers. Nonetheless, this does not mean that the food and drinks industry is not innovative, but rather that innovation may follow different trajectories and impact products in different ways (e.g. in regard to packaging and conservation) that are sometimes even aimed to be "hidden" from obvious recognition like low-fat, low salt or low sugar products that should taste like the original.

Firm size and innovativeness.

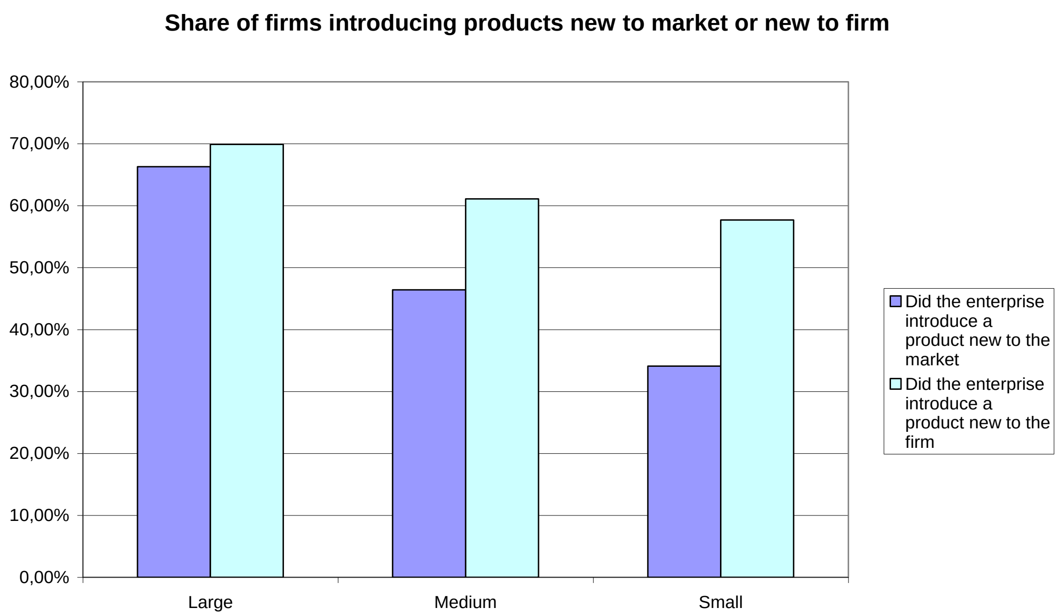
There appears to be a strong relation between the possibilities and capacities to innovate and firm size. CIS4 micro-data indicate that the share of large companies engaged in innovation is more than twice as high as for small companies. This holds for innovation activities in goods, services and processes, but also for the market introduction of new or significantly improved products and services and the introduction of new production methods. The share of large firms that introduce new products to the market is nearly twice as high the share of small firms doing the same. For the introduction of products new to the firm but not new to the market, the differences between large, medium and even small companies are less pronounced. Figures indicate that even small companies are engaged in internal innovation, i.e. renewing or changing their own product palette. Yet since they score much lower in new-to-market products, they may orient themselves on the activities of others and 'copy' successful products.

Figure 1.1 Innovation indicators by firm size



Source: Eurostat CIS4

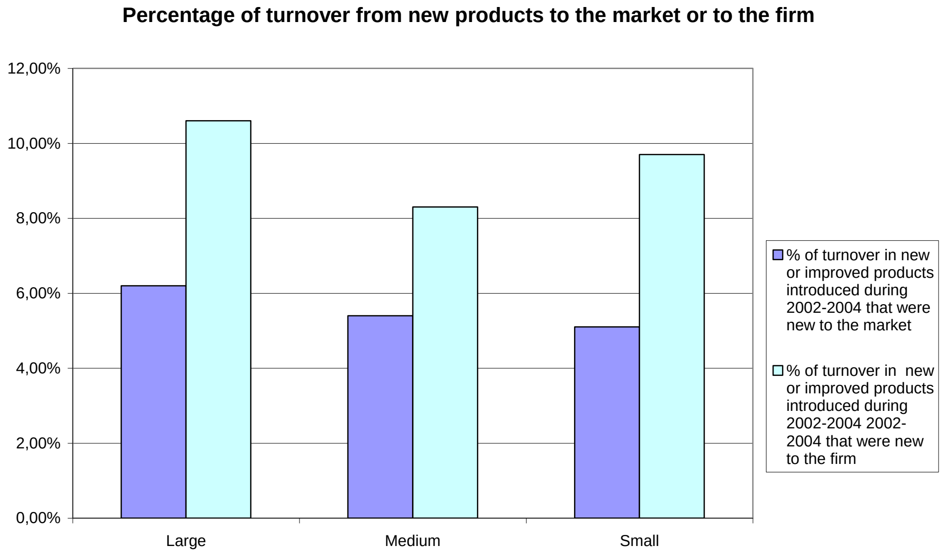
Figure 1.2 Share of firms introducing products new to the market or firm



Source: Eurostat CIS4

Looking at the turnover from new to market and new to firm products (figure 1.3), the differences between large, medium and small firms do not look very huge, which could indicate that new products can be of advantage for all company sizes alike, whereas it has to be kept in mind that the overall shares of turnover from new-to-market and new-to-firm products is much lower than the CORE NACE average.

Figure 1.3 Percentage of turnover from new products to the market or firm



Source: Eurostat CIS4

As a general conclusion it can be said that the data supports the assumption that large companies are the innovation leaders. But medium-sized companies also show innovation potential, especially in regard to new products to the specific firm. Large companies seem to be the overall innovators who bring new products to the market, whereas medium-sized and even small companies seems adopt successful products and processes. Although small firms show the lowest scores on all innovation indicators so far they nonetheless seem not to be much worse than large firms especially in regard to the share of products new to the firm as well as the percentage of turnover of products new to the firm.

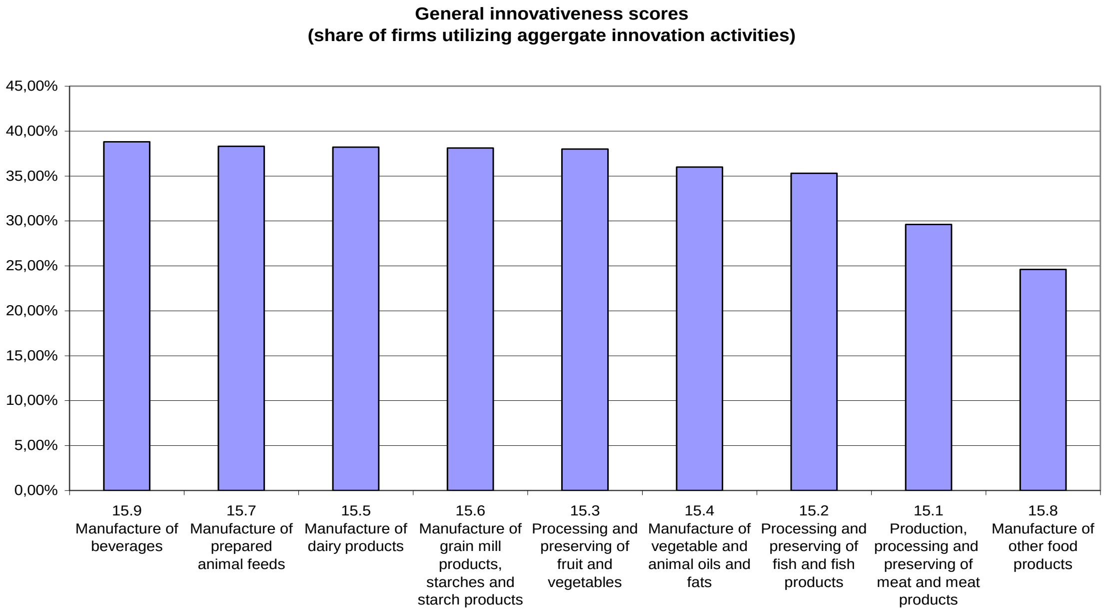
Innovativeness at sub-sector level.

Looking at the product palette in stores and supermarkets, one would assume that the dairy and cereal sectors are among the most innovative, given the relatively large amount of functional yogurts and milk products (e.g. probiotics) as well as functional foods that fall under the category of cereal products (e.g. morning cereals and bars). Also the drinks sector appears to be quite innovative given the presence of sports and functional drinks. Fruits and vegetable juices, however, are listed under “manufacture of food products”.

In terms of aggregated innovation activity, the drinks sector (DA 15.9) scores highest, closely followed by the production of animal feed (DA 15.7), dairy products (DA 15.5) and grain and mill products (DA 15.6). Least innovative in this ranking are meat production (DA 15.1) and the category “other food products” (DA 15.8). The grain and mill products sector (DA 15.6) shows the highest share of market introductions of new or significantly improved products, followed by dairy products (DA 15.5). Meat processing and “other food products” again score much lower in comparison.

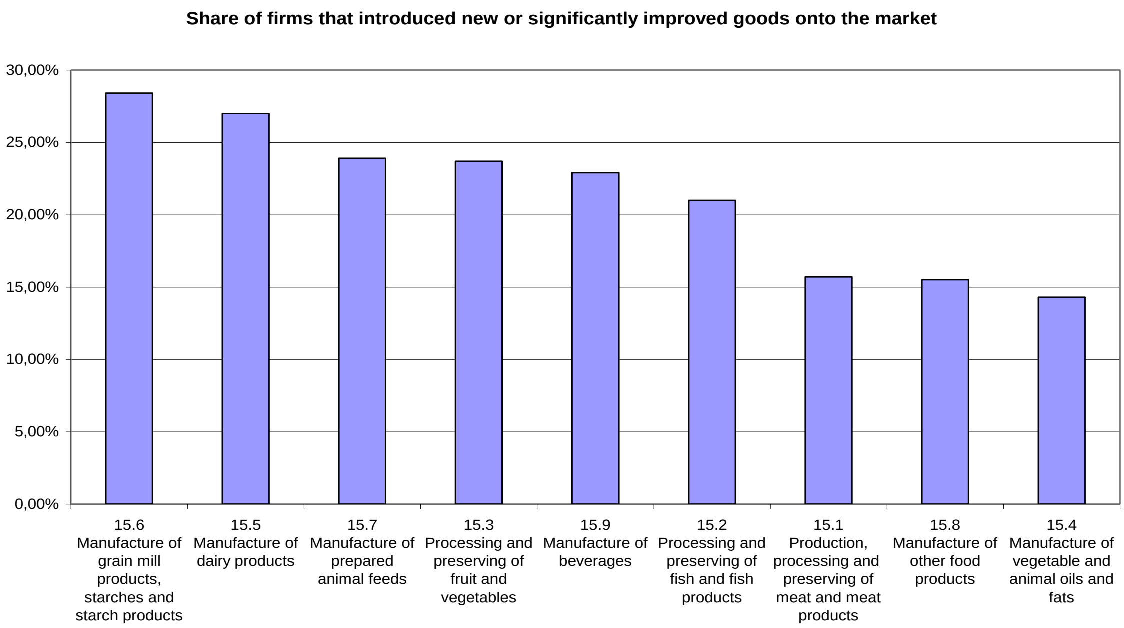
If we compare the sub-sectors in terms of introductions of new or significantly improved products to the market, the picture is similar to the overall innovativeness scores, with grain and mill products, dairy and animal feeds scoring highest and meats, other foods and oils and fats scoring lowest. The overall share is below 30% for even the leading sub-sectors.

Figure 1.4 General innovativeness score



Source: Eurostat CIS4

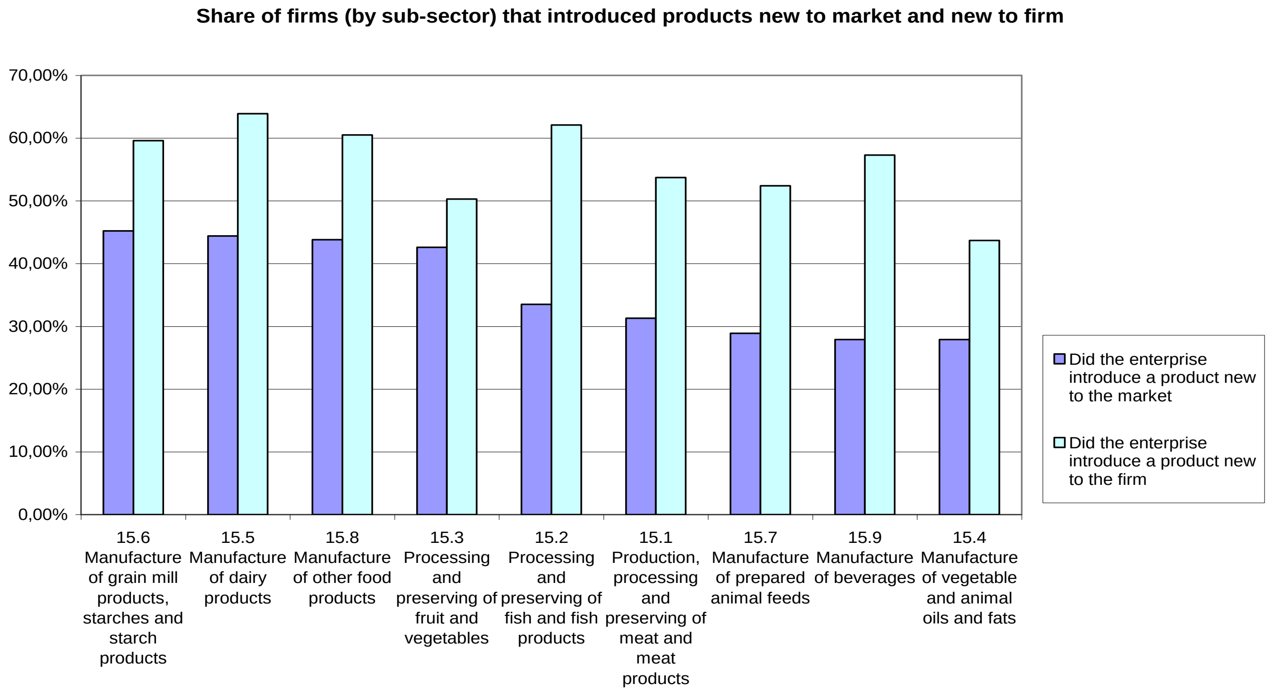
Figure 1.5 Share of firms that introduced new or significantly improved goods onto the market



Source: Eurostat CIS4

While it may at first glance be surprising that animal feeds have a higher score than many sub-sectors with products for human consumption, the animal-feed and pet food sector offers much specialized (e.g. special food for elderly pets), functional and even medicinal food (e.g. special food a). Another major reason is less strict regulations for animal feed and pet food. But also here – as with food for human consumption – the differences in quality and functionalities of pet foods can be huge.

Figure 1.6 Share of firms (by sub-sector) that introduced products new to the market and the firm



Source: Eurostat CIS4

The figures in regard to introducing products that are new to the market and new to the firm (without indicating if they are significantly improved) show a slightly different picture in some respects. In general, the share of products new to firm (but not new to market) is much higher than the share of new-to-market products, which is generally not surprising and could also hint towards a strategy of copying successful products from other companies. Also again here grain and mill products and dairy products are the leaders, whereas “other foods” also score high, but animal feeds low.

Taking together, one can conclude that manufacturers of grain and mill products and of dairy products are the most innovative sub-sectors as compared to the others. This is not much surprising as already mentioned at the beginning if observing the large variety of functional dairy products (especially yogurts and similar products) as well as cereals and functional food bars that are often marketed as especially healthy with much value added.

Meat processing gets a low score on all indicators, whereas here many innovations are possible in principle, especially in regard to ingredients, fat reduction and preservations. But meat processing is also highly regulated, also in regard to trademarks as reflected in the German “Reinheitsgebot” for beer and sausages, and innovations often require much knowhow that can hardly be achieved by smaller firms. The idea of a German butcher from a small company to produce a low-fat sausage, for example, has due to the necessary physical and biochemical know-how only become realized with the help of the Fraunhofer Institute that shares the patent with the butcher (IDW 2008). Many production workers in food and drinks companies, especially in small firms are due to resources and skills also often trained to reproduce existent production processes instead of experimenting with new ways. The mastery of producing some food and drinks products, especially famous traditional items, often especially lies in the skill of exactly following the production processes that have been handed down by generations.

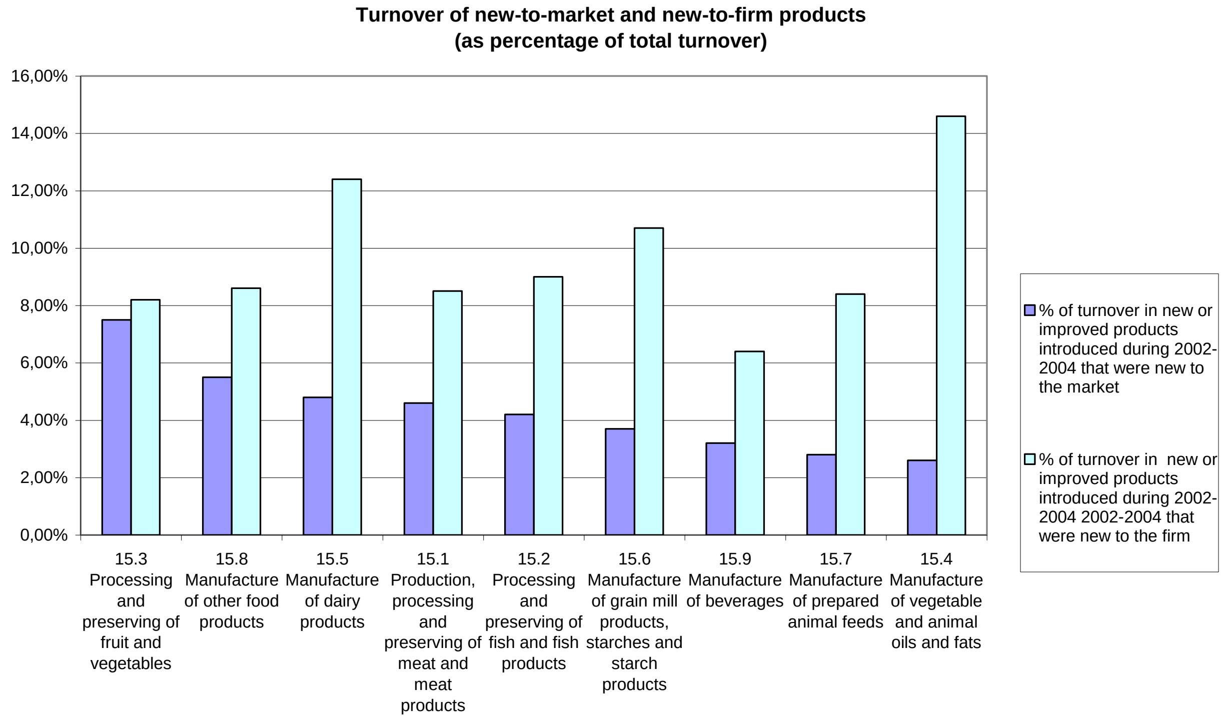
Since meat consumption is also a health issue, innovations and support for innovations for improved, healthier and safer products may be of particular importance. General targets could be the reduction of fat (especially saturated fats), less salt and a further reduction or substitution of controversial ingredients that pose potential health risks (e.g. nitrite or phosphate). However, the controversial ingredients have a specific function for the product and their substitution needs capabilities in research and development. This does not only apply for meat products, but actually for all processed foods and drinks.

Turnover and success of new products.

The food and drinks manufacturing sector scores significantly below CORE NACE average (i.e. compared to the average of the major manufacturing sectors) in regard to shares of total sales of new-to-market products as percentage of total turnover, with a share of only 4.78% of total turnover, against a CORE NACE average of 8.43%. Within food and drinks sub-sectors, turnover of new-to-market products (as percentage of total turnover) is lower for all sub-sectors than turnover from products new-to-firm but not new to market. The discrepancy between these two is especially high in the animal fats and vegetable oils sub-sector. Fruit and vegetable processing and preservation score highest in the shares of turnover from new to market products and both shares (new to market and new to firm) are nearly equally high.

Surprisingly, the apparent innovation leaders – dairy and grain/mill products – score only in the middle on turnover shares of new-to-market products, but are among the three top-performers in regard to new-to-firm products. Looking at the payoff of innovation, these findings seem to suggest that the introduction of a new product does not necessarily translate to economic success (e.g. with grain/mill products) and that some sectors like meat processing that who generally introduce fewer new-to-market products can generate higher turnover with their fewer new-to-market products.

Figure 1.7 Turnover of new-to-market and new-to-firm products (as percentage of total turnover)



Source: Eurostat CIS4

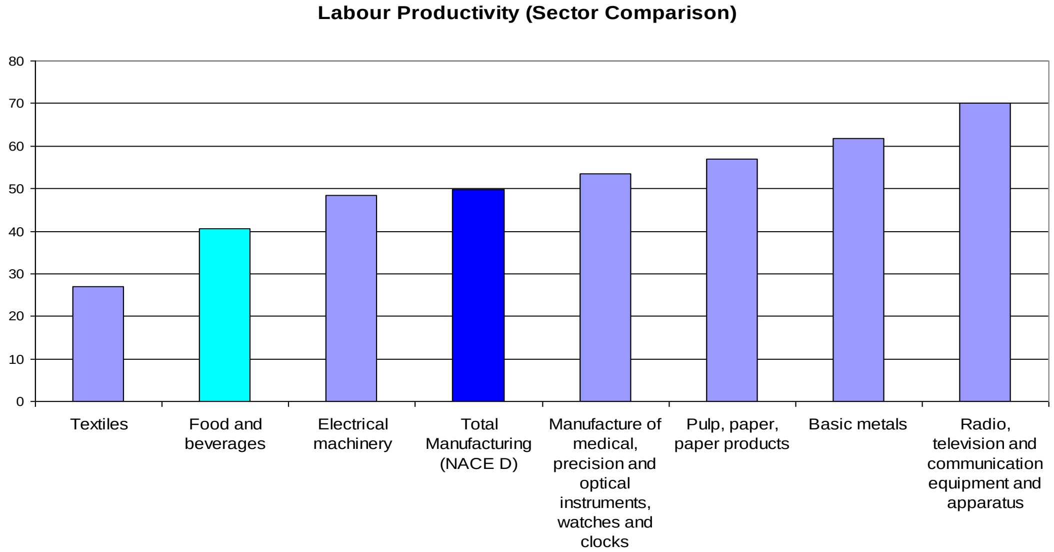
Labour productivity.

Looking at other Eurostat data (SBS), the apparent labour productivity (defined as gross value added per person employed) in the food and drinks manufacturing industry is below manufacturing average (cf. figure 1.8). Only the textile manufacturing industry shows lower figures than food and drinks production, but all other selected manufacturing sectors which include metal production, pulp, paper and paper products, basic metal production, manufacture of machinery, of television and communication equipment and apparatus and of medical, precision and optical instruments, watches and clocks show higher values score higher. These figures taken together with the sector's considerable high share of employees out of the whole manufacturing sector seem to support the assumption that the sector is rather labour intensive and underperforming in respect to productivity.

However, the food and drinks industry is currently a major growth factor for the robotics industry with a 20% increase in shipments from 2006 to 2007 (World Robotics, 2008). As robots are becoming more "intelligent", especially in regard to pattern recognition, more sensitive (being able to handle fragile objects and being fitted with improved sensors) and cheaper, the growth is likely to continue.

Looking at it from an international perspective, with an apparent labour productivity of 41,800 euro in 2004 (Eurostat, 2007), the food, drinks and tobacco manufacturing industry the EU-27 lagged behind the US, Canada, Japan and Australia (CIAA). Yet marked differences exist between sub-sectors, the processing and preserving of fish and fish products being at the lower end with 29,400 euro and drinks at the upper end of the scale with 70,000 euro.

Figure 1.8 Apparent labour productivity (gross value added per person employed)

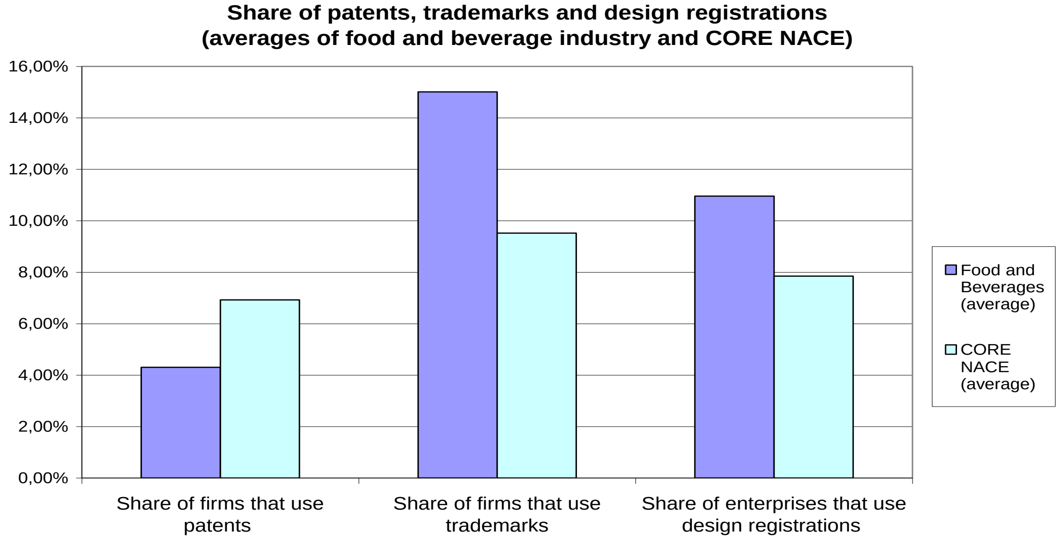


Source:

Source: Eurostat SBS (data for 2005)

Intellectual property rights protection. Since innovations represent a potential for (future) revenues, companies are interested in preventing others from copying the ideas, recipes and products. Although the food and drinks industry scores significantly lower in regard to patents than the CORE NACE average, trademarks and design registrations are used to a much higher degree within food and drinks manufacturing.

Figure 1.9 Intellectual property rights (comparison between F&B industry and CORE NACE)

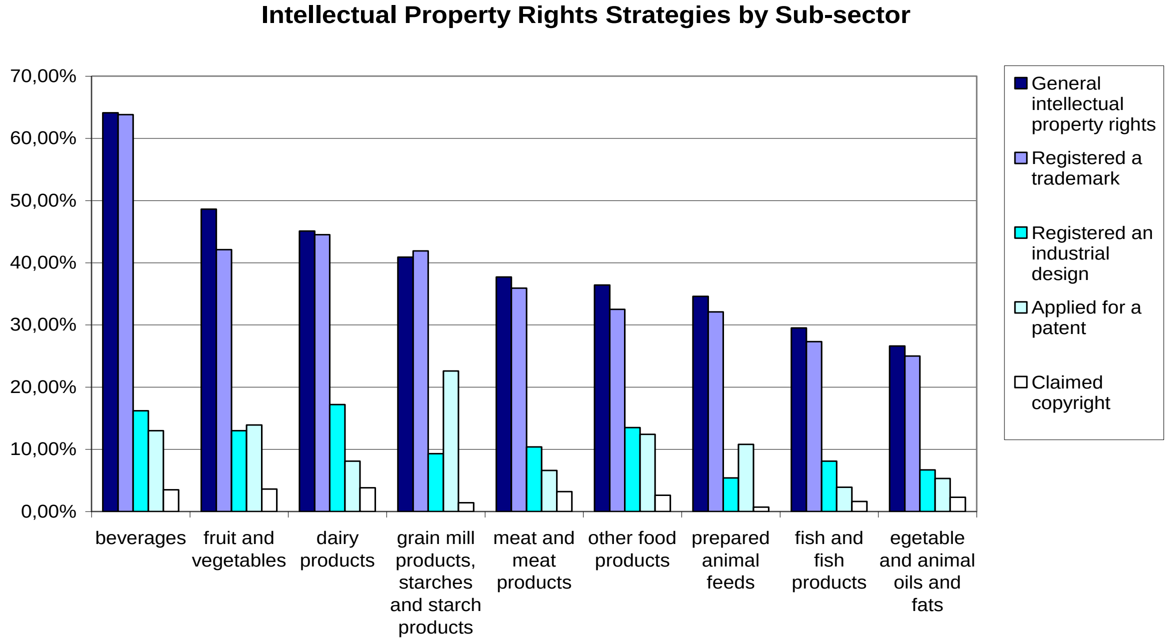


Source: Eurostat CIS4

Looking at the sub-sectors, the highest share in patents can be found in the sector of grain mill and starch products, followed by fruit and vegetable processing and preservation, drinks and other food products. The lowest figure is with fish processing and production. However, some figures for fish manufacturing may be listed within other NACE categories, e.g. fishery, since modern fishery is often already highly automated (e.g. large factory fishing ships).

In regard to trademarks, the drinks producers possess the highest share, which may not seem surprising given the large amount of trademarks for different drinks, especially in regard to energy/sports drinks, and alcoholic drinks. Here again fish production the lowest.

Figure 1.10 Intellectual property rights by sub-sector



Source: Eurostat CIS4

Trademarks and design registrations are apparently most important for the food and drinks industry – even more important than patents. Trademarks and design registrations can help producers to set their products apart from imitators and competitors and emphasize their originality. However, in contrast to patents, trademarks are not necessarily an indicator for innovation, at least not in regard to on-going innovation. Trademarks could even have an effect that rather hinders product innovations, since once introduced and established, consumers are may expect a certain continuity in association with a certain trademark and significant changes to a trademarked product could even pose legal problems in regard to authenticity.

But trademarks can also be prone to forgery and infringement and subtle differences between the originally trademarked product and a product infringement might perhaps not be easily recognized by the customer (similar to infringements of labels in designer clothes, for example). The unauthorized reproduction of a patented product or process would count as patent infringement, whereas the production and sale of a product that is similar in taste, texture etc. to a trademarked (food/drinks) product that runs under a different name may not necessarily be regarded as infringement. Large retailers, for example, often produce and sale their own store brands/own brands which are similar to trademark/label products, but run under different names and are often much cheaper. In some cases, the manufacturers of store brands/own brands are even the same as the manufacturers of trademark and brand-labelled products.

In this sense, trademarks are much less about evaluable in substance than patents and much more about psychological effects in the customer as well as factors of trust, binding and prestige, where differences in products or their advantages may not even be objectively measurable. Some studies have shown that many people are not able to tell the difference between Pepsi and Coca Cola, for example, when not knowing which brand they are being served, i.e. in blind-tests. The results of the diverse tests for telling the difference between Pepsi and Coca Cola are disputed, partly not due to scientific, but due to economic reasons (some tests even suggest that people prefer the taste of Pepsi over the market leader Coca Cola), whereas other interpret the data that the differences (e.g. sugar/carbonation ratio) between these two drinks are actually too small to come to reliable conclusions. Therefore the test results are disputed and it is difficult to get an objective picture in this regard, also due to interferences with commercial interests. But rather recent neuroscientific tests in regard to Coke and Pepsi preference also suggest the great importance of brand knowledge (McClure et al., 2004).

The lower use of patents in the food and drinks manufacturing industry could also stem from particularities of the products of the sector. While food/drinks products and processes for food/drinks production are generally patentable, e.g. low-fat products or products that due to shape or composition have visible advantages, most of them do not fulfil the criteria of usefulness, novelty and non-obviousness for getting a patent granted. Recipes make up the major and important part of food and drinks production, but recipes are generally not patentable because in the large majority of cases they do not fulfil the criteria novelty and/or non-obviousness. Copyrights are also not feasible in most cases of food and drinks production, because generally ingredient listings can not be subject to copyright protection (e.g. because they represent statements of facts) and copyrighting the final food/drink product is difficult and depends on the interpretation of its “aesthetic” (vs. a “functional”) property. In this respect it looks like the logical choice that trademarks (and possibly trade-secrets which have not been subject to the statistic) are the major choice of intellectual property protection in the food and drinks manufacturing industry. In this sense, it would be expected to be rather the production processes, specific treatments (e.g. in regard to preservation or taste improvement such as using micro-encapsulation) or specific ingredients (e.g. biotechnological processing agents) that could be patented, but these may also be developed outside the food and drinks industry (e.g. in industries dealing with machinery, biotechnology or nanotechnology R&D).

The development of patentable innovative production methods and resulting innovative products also requires substantial scientific and research skills that can be especially difficult to obtain in small companies. The idea of a German butcher from a small company to produce a low-fat sausage, for example, has due to the necessary physical and biochemical know how only become realized with the help of the Fraunhofer Institute research organisation that shares the patent with the butcher (IDW 2008). Many production workers in food and drinks companies, especially in small firms are due to resources and skills also often trained to reproduce existent production processes instead of experimenting with new ways. The mastery of producing some food and drinks products, especially famous traditional items, often especially lies in the skill of exactly following the production processes that have been handed down by generations.

This suggests that it is strategically reasonable for the food and drinks industry to make more use of trademarks, because trademarks are a good means for marketing, getting the customer’s attention and customer binding. New ways for intellectual property rights protection better suitable for the food and drinks industry as well as improved knowledge transfer from other sectors (e.g. biotechnology, chemicals, ICT) could improve the applicability of patents and foster innovativeness by providing better protection of inventions within the food and drinks industry.

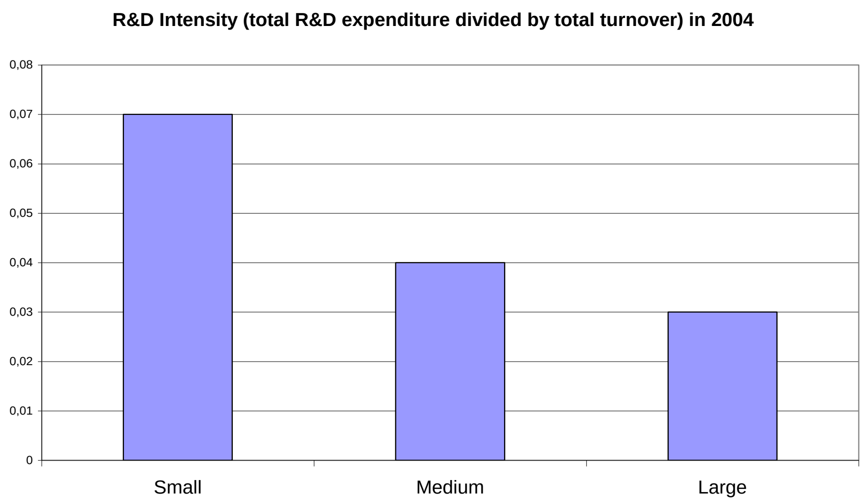
Food labelling could also foster or signal innovativeness, especially as the regulation of labels (e.g. in regard to health claims and ingredients) have become stricter. But labels can also be used to signal tradition and continuity and thus freeze innovativeness.

R&D intensity, investments and funding.

R&D investments by large individual firms can be seen as an important indicator for their innovation effort. Especially large food and drinks manufacturing companies, and in particular multinationals, are much involved in research and development activities for new processes and new products. However, large companies comprise only less than 1% of the total number of companies in the European food and drinks manufacturing industry (0.86% with 250 or more employees accounting for 51.54% of total turnover. The vast majority in the food and drinks industry are SMEs, 78.6% having even fewer than 10 employees. These micro-companies accounting for 6.95% of the sector's turnover are not included in CIS4 statistics; CIS4 data do not provide data about their innovativeness therefore.

As a comparison with the CORE NACE average revealed, the food and drinks manufacturing industry lies within the average range in regard to R&D expenditures defined as share of total turnover. When we compare small, medium and large firms, the R&D intensity (defined total R&D expenditure total turnover) is largest for medium sized firms and lowest for large firms. This looks quite unexpected since the number of large firms engaged in intramural R&D is much higher than that of small firms (figure 1.12) and it is assumed that the food and drinks industry does not have a large spin-out tradition of highly innovative start-ups as is the case with biotechnology and ICT firms.

Figure 1.11 R&D intensity

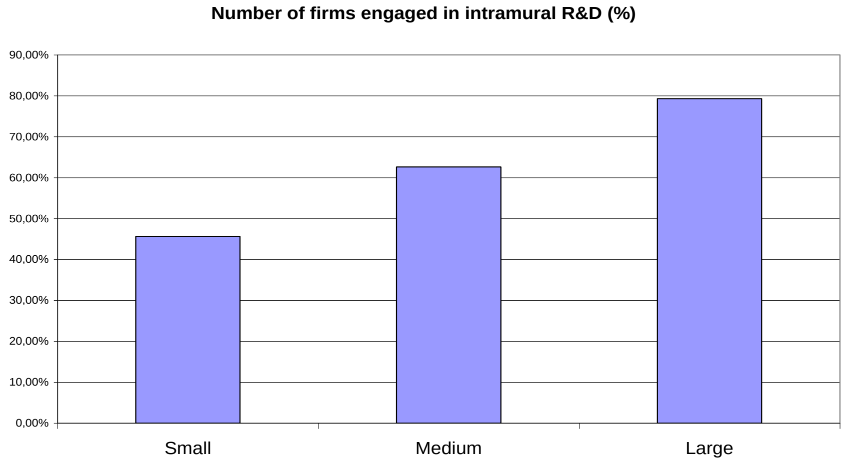


Source: CIS4 Eurostat

CIS data indicates that small firms invest more in R&D than large firms relative to their total turnover. Coupled to the earlier findings this would indicate that the share of turnover from new-to-market new-to-firm products of small firms is not much worse than for large firms. It could possibly reveal their strategy of observing successful products on the market and then producing similar products themselves.

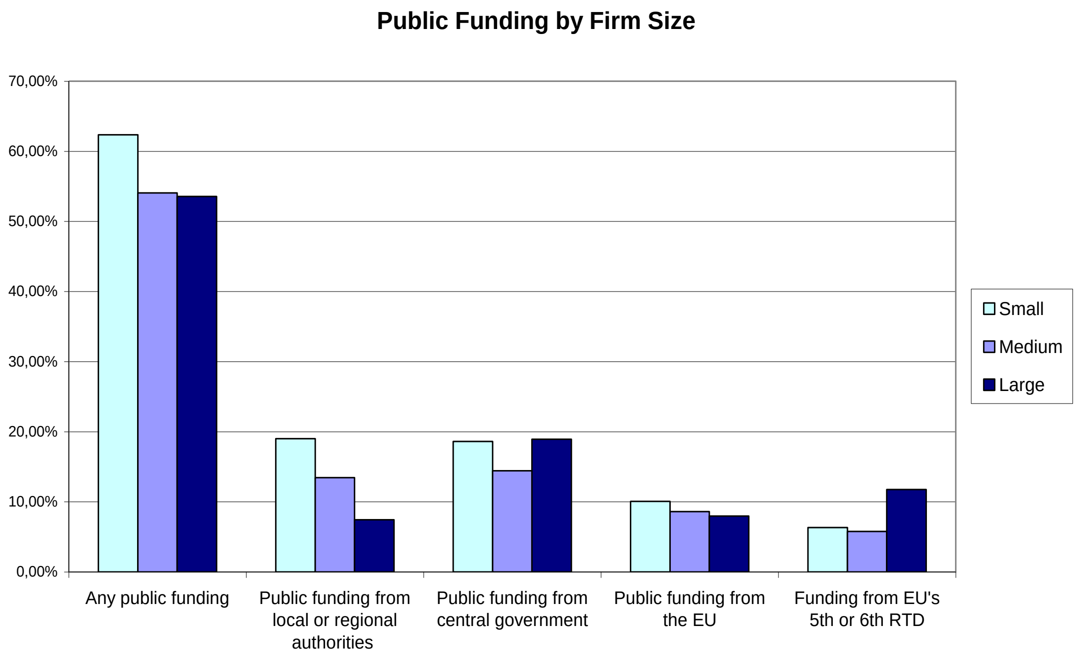
Public funding for innovation figures show that more small firms receive public funding than large firms. Yet the data does not say anything about the size of public funding (euro's); also differences do not seem disproportionally large.

Figure 1.12 Number of firms engaged in R&D



Source: Eurostat CIS4

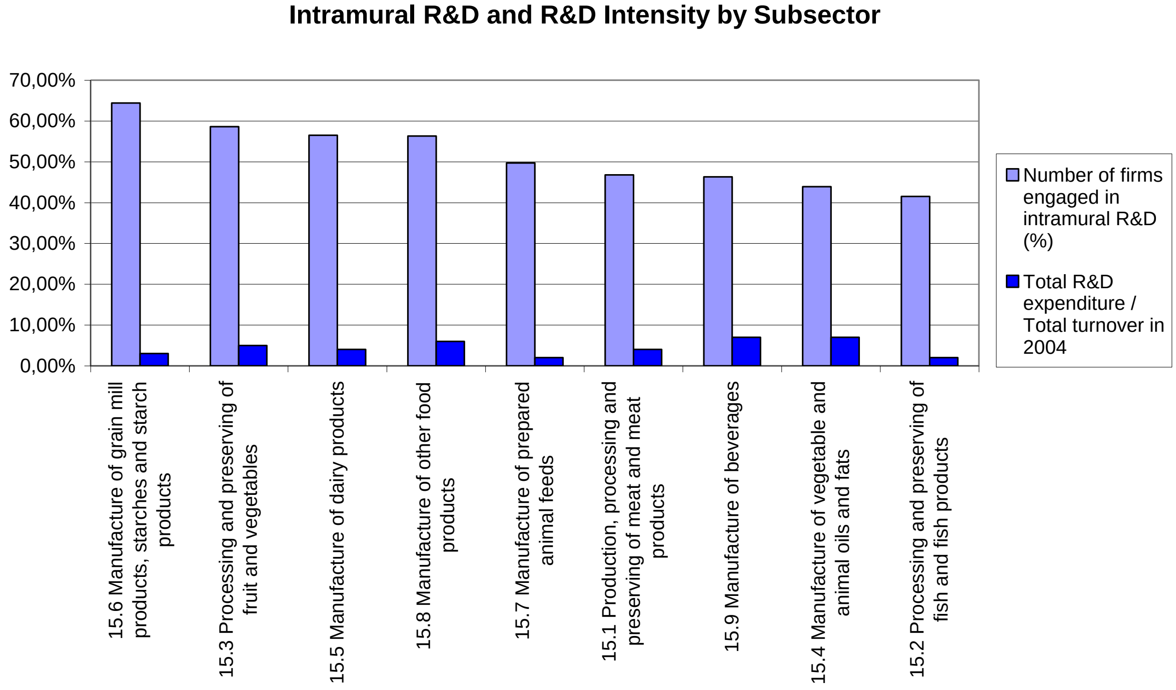
Figure 1.13 Public funding for innovation by firm size



Source: Eurostat CIS4

Small firms receive especially much funding from local and regional authorities, whereas in regard to the RTDs, large firms score much better than small or mid-sized companies, that both have nearly the same shares. This can also be due to the formalities and application procedures of the EU's RTDs which large firms are likely to be able to handle better.

Figure 1.14 Intramural R&D and R&D intensity by sub-sector



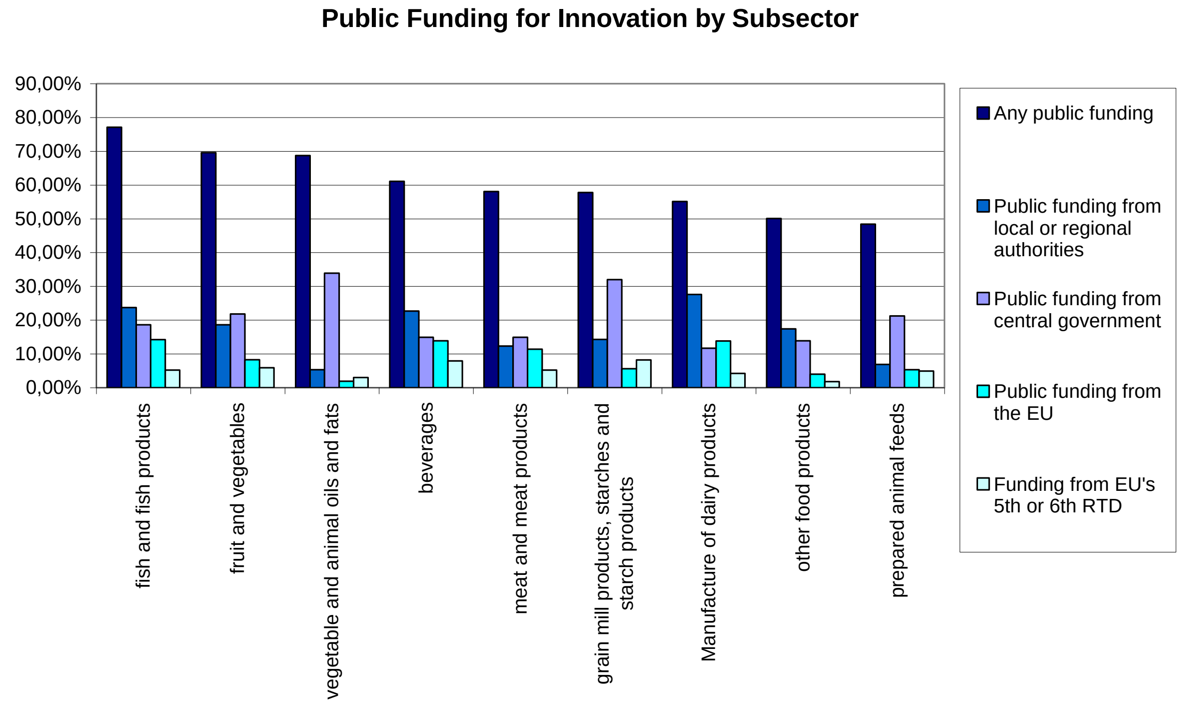
Source: Eurostat CIS4

As a conclusion it can be said small firms are getting support for R&D activities and that they seem to be successful in introducing new products to their firm. Large firms score better in general innovativeness and the introduction of products that are new to the market and are better integrated into R&D funding schemes from the central government and the EU's RTDs.

A look at the sub-sectors reveals that in regard to the number of firms engaged in intramural R&D, grain and mill products are leading, followed by processing of vegetables, dairy production, and other foods with nearly similar scores. Fish production scores lowest. Noticeable is that for the R&D intensity (defined as total R&D expenditure divided by total turnover) the drinks sector and the manufacturing of oil and fats scores comparatively high, whereas those sector's scores on intramural R&D are within the lower end.

With regard to funding, the fish manufacturing sector gets the highest share of public funding, which is interesting since this sector scores comparatively low on all innovation indicators. Vegetable processing and the sector producing oil and fats scores second highest on public funding, which could also be related to health promotion strategies. Oil and fat manufacturers also get the most funding from central governments.

Figure 1.15 Public funding for innovation by sub-sector



Source: Eurostat CIS4

If comparing the public funding for innovativeness with the general innovativeness scores, it looks as if many of the sectors receiving more funding score worse in general innovativeness and vice versa. This applies especially for fish and fat an oil production (lower innovativeness score but comparatively more funding) and the animal feed and dairy sectors that are higher on innovation scores but lower on funding. However, the general innovativeness scores do not show really high differences between the subsectors, except for meat products and other products.

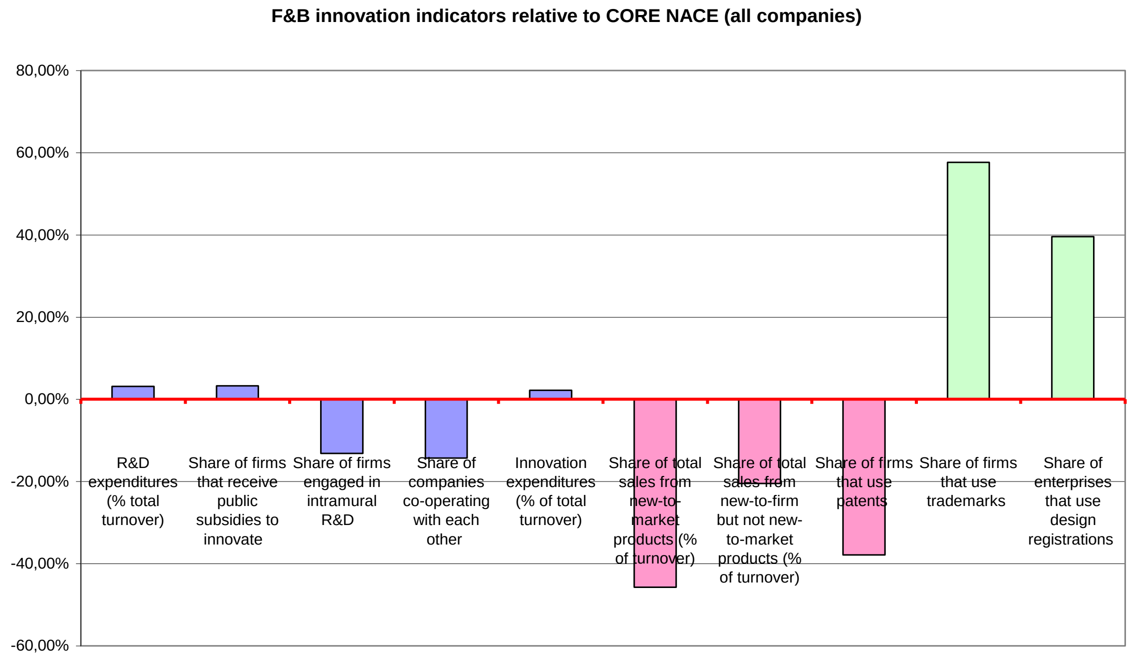
1.3 Common set of indicators

Innovation performance

How does the food and drinks sector compare to other sectors in terms of innovation performance? Based on a common set of indicators (see Box 1 for methodological aspects), a comparison on ten different core indicators was made, including R&D expenditure, public subsidies, co-operation, innovation mode and expenditure, turnover of new-to firm and new-to-market products and the use of patents, as well as trademarks and design registrations.

A comparison with the CORE NACE innovation performance indicators reveals that food and drinks score below CORE NACE average, especially on share of sales from new-to-market products, share of sales from new to firm products and share of firms using patents. Two types of comparisons were made, one based on the results for *all firms* included in the CIS4 survey (see figure 1.16) and one for the sub-set of innovative firms only (see figure 1.17). The graphs show the relative differences of the CIS4 innovation indicators to the CORE NACE average.

Figure 1.16 Comparison of F&B industry and CORE NACE innovation indicators (based on all firms)

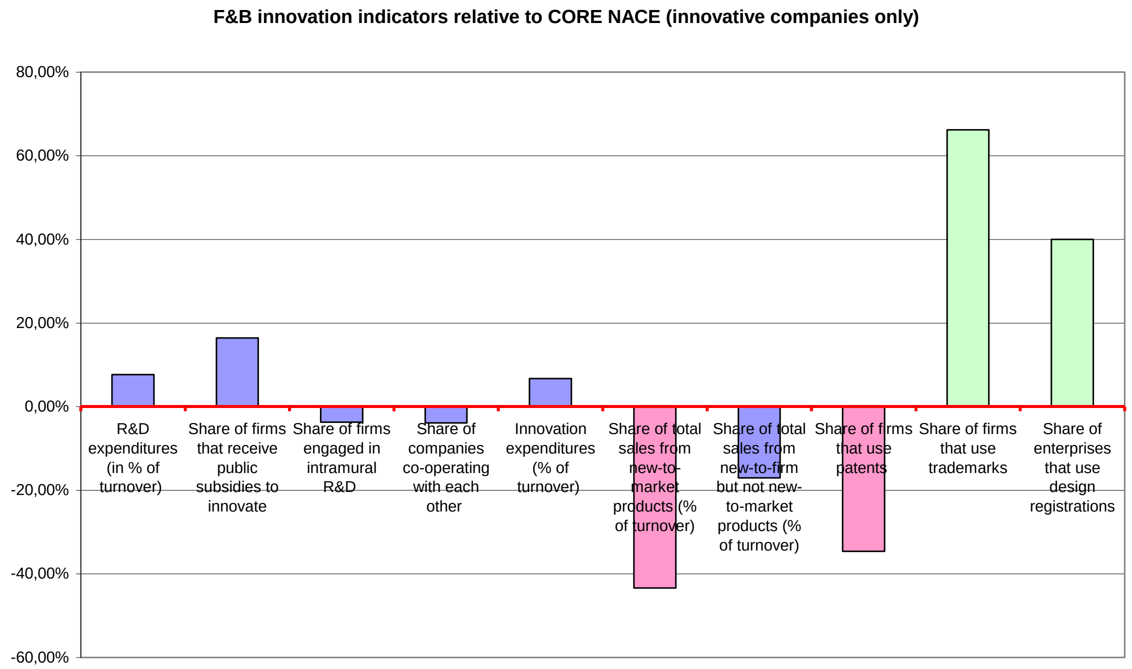


Source: Eurostat (public CIS4 data)

The red bars represent the innovation indicators that scored beyond average (i.e. the share of food and drinks manufacturing firms who make use of this practice scores below a percentage GAP of 80%, in this visualisation all below -12%) and are thus defined as significantly below CORE NACE average. These include the use of patents and the share of new-to-market and ne-to-firm (but not new to market) products. Significantly above average (in this visualisation all above 20%) has been the usage of trademarks and design registrations, which therefore seems to represent a favoured strategy in the food and drinks manufacturing industry as compared of the use of patents which falls significantly below average. All other indicators are still considered within the scope of “average” to the CORE NACE, however the figures in regard to intramural R&D and co-operation between companies is slightly beyond CORE NACE average. When we only look only at the companies that have been defined as “innovative” within CIS4 the picture looks only slightly different.

For innovative food and drinks manufacturing companies the share of sales from new-to-firm still is within the definition of the CORE average. The use of trademarks is even higher with innovators, which again indicate that trademarks are an important dimension of innovation within the food and drinks sector. For other indicators no much difference exists between firms defined as innovators in CIS4 and non-innovators.

Figure 1.17 Comparison of F&B industry and CORE NACE innovation indicators (based on innovative firms)



Source: Eurostat CIS4

2 Carriers of innovation

2.1 People – skills for innovation, education and training

Skills and educational profile

The skills and educational profile of the food and drinks manufacturing industry is two-pronged. On the one hand, many jobs within this sector are classified as “elementary occupations” involving activities necessitating only lower level skills. On the other hand highly specialized or interdisciplinary scientific personnel is required, especially for innovation activities. Scientific advances as well as new regulations also cause changes for qualification profiles or even lead to new job categories. Higher demand in regard to hygiene and standards also call for new training and skills updates for persons working in elementary occupations.

According to CIAA statements, many European food and drinks manufacturing industries, especially larger food companies are experiencing a shortage in high-skilled workers, especially food scientists, food technologists and food engineers, which is seen as a great hampering factor for innovation (CIAA 2008). According to a study published by the Institute of Food Science and Technology (IFST) in 2006, more than half of employers in the food and drinks manufacturing industry complained about a shortage in food scientists and technologists and about the fact that vacancies were hard to fill due to missing candidates (cf. Innovations Report 2006). These concerns are still persisting globally as the IFT president has stated in a 2008 interview (cf. AP-Foodtechnology, 2008). It appears relevant to promote the interest in food-specific scientific qualifications in the early stages of education (cf. HLG, 2008:10).

The share of employees with higher education was lower in food and drinks manufacturing than the manufacturing average. According to the Europe INNOVA report from 2008, the share of employees with higher education in the food, drinks and tobacco manufacturing sector was with a 6.6% share almost half of the manufacturing average with a 13.7% share. However, these findings could not be assessed within this report due to lacking (Eurostat) data about the education levels by NACE sector.

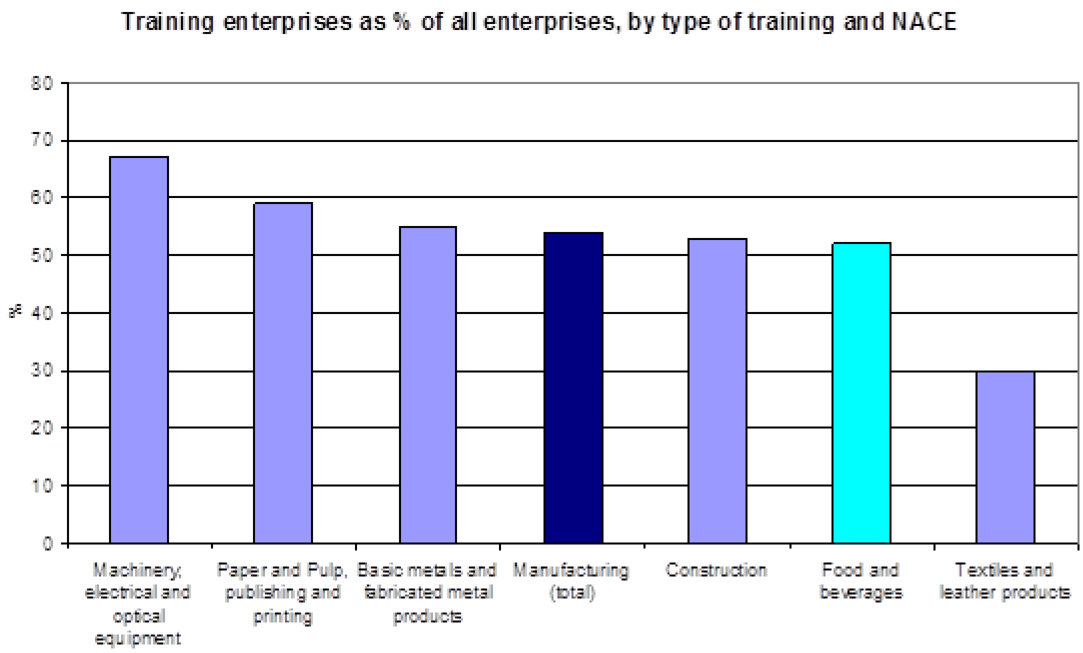
Lack of ICT skills

ICT-related skills (e-skills) are already very important today and expected to become even more important in the future. E-skills are a necessary condition for innovativeness and less innovative industrial sectors and firms are likely to lag behind in ICT-related indicators. Publicly available Eurostat data does not focus on NACE sectors. The European Commission’s e-business w@tch does, however, provide data on the usage of ICT and ICT skills in the food and drinks sector (European Commission, 2006). The findings show that especially SMEs and small companies show a lack in e-skills among the employees and only 50% of large companies reported practicing regular ICT training. Company size and costs are named as the main barriers to ICT implementations.

Training

In 2005 52% of all EU25 food, drinks and tobacco companies made use of in-company training, a share that is below the manufacturing average. The food and drinks industry has the second lowest share after manufacturing of textile and leather products (which is especially low) and is also lower than construction, metal production, paper and pulp manufacturing (including publishing and printing) as well as manufacturing of machinery, electrical and optical equipment (which has the highest shares). However, the difference of the food and drinks industry to the average of the manufacturing total is only 2%, but the leader (machinery, electric and optical equipment) has a 15% higher share of training enterprises than food and drinks manufacturing. Not surprisingly, data indicate that large companies are more engaged in training than medium and small companies, whereas small companies score lowest with a share of under 50%.

Figure 2.1 Training enterprises as % of all enterprises, by type of training and NACE

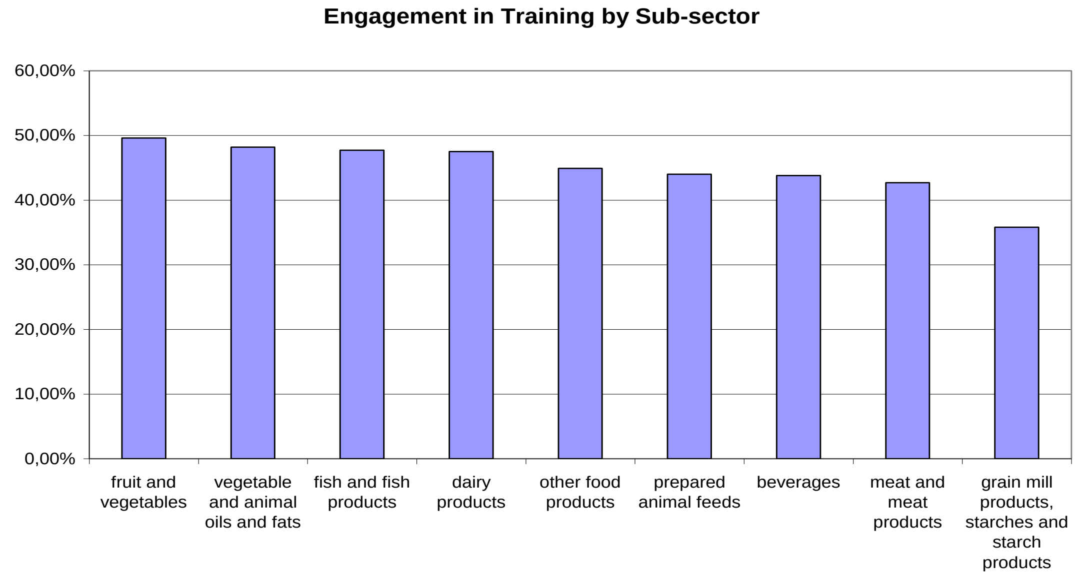


Source: Eurostat (obtained 2009)

At the sub-sector level, the lowest score can be found in the grain and mill manufacturing sector and the highest scores in fruit and vegetable manufacturing. Except for the grain and mill manufacturing sector all other shares of firms engaged in training are above 40% but below 50%.

Some European countries are putting great efforts into training efforts for the food and drinks industries. These range from basic hygiene training to specialized advanced training courses. Up skilling and life-long-learning are also emphasized as important methods to align qualifications with demands and react to the new scientific and technological changes that affect the food and drinks industry.

Figure 2.2 Engagement in training by sub-sector



Source: Eurostat CIS4

A variety of programmes has been initiated, especially in the UK, to improve the skill availability and competitiveness of the food and drinks manufacturing industry. Many of these also deal with rather basic issues like hygiene, e.g. mandatory training programmes in HACCP - Hazard Analysis and Critical Control Points practices. The UK has also set up an “Academy for Food and Drink Manufacturing”, as a joint venture between the government and the industry which provides extensive vocational education and training programmes. Similar programmes have also been set up in other European countries, e.g. the "ZIEL-TUM-Akademie Ernährungs- und Lebensmittelforschung" in Germany that focuses on nutritional sciences. In general great efforts are being undertaken nationally and on the EU-level to improve the skills situation in the food and drinks manufacturing industry and increase the number of students and university graduates in related areas.

Robots, artificial intelligence and automation

The food industry is currently a major growth sector for the robotics industry (World Robotics, 2008). As robots are becoming more “intelligent”, especially in regard to pattern recognition, more sensitive (being able to handle fragile objects and being fitted with improved sensors) and cheaper, the growth is likely to continue.

ICT solutions are also getting increasing attention in the food and drinks manufacturing industry and logistics, especially in food chain management and traceability. If the trend is also going more towards the direction of personalised foods and drinks and the customised engineering on bio-scientific bases, computer assistance will become necessary for food development. According to a Frost and Sullivan report from 2009, the food and drinks industry is increasingly becoming a major purchaser of wireless technology and robotics (cf. Control Engineering Europe, 2009). A fully automated food factory is generally thinkable, but has its downsides (e.g. unemployment).

If robots and computer technology progresses, fully automated food and drinks factories may not be that difficult to implement within the next 20 years. At the same time this would imply a major change, since currently the food and drinks manufacturing industry is the largest employer in European manufacturing. A declining active workforce because of ageing, on the other hand, could make further automation in the food and drinks industry a more acceptable solution.

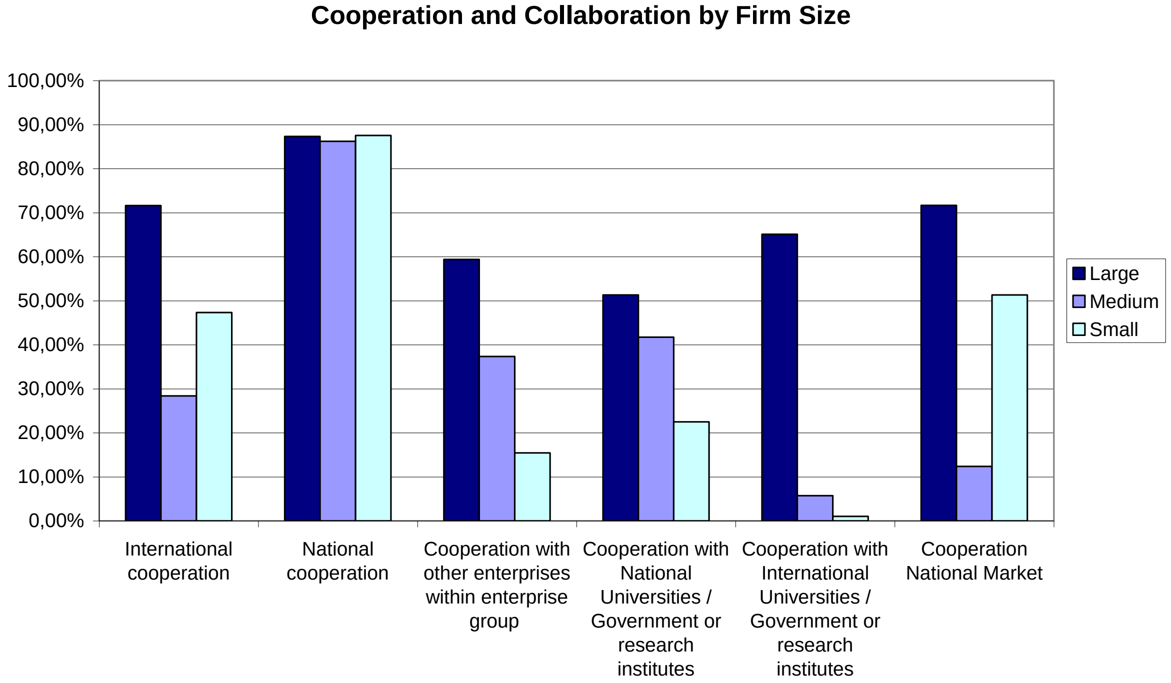
The latest development is a deboning robot for the meat processing industry which is able to perform a task that has previously been difficult to automate but now even achieves a better performance than skilled workers.

2.2 Organisations and collaboration

International and national collaboration

In regard to international collaboration, large firms show the highest shares with over 70% of large firms being involved in international cooperation. Somewhat surprising may be that not medium sized but small sized companies have the second highest shares (47%) in international cooperation. However it is not very clear how exactly collaboration is defined and in how far it has necessarily be related to innovativeness. But as the data also shows that medium sized companies have the highest export shares, it is also surprising that their share of international cooperation is comparatively low (below 30%). On all items covered under this topic in CIS4, medium sized firms score lowest. Small companies also score quite high (much higher than medium-sized companies) on cooperation with the national market. However in regard to cooperation with international and governmental research institutes, large enterprises the share of large firms is by far higher than for mid and small sized firms. This is also in line with the findings mentioned previously in regard to funding from RTDs. In regard to national cooperation no big differences exist between firm sizes.

Figure 2.3 Cooperation and collaboration by firm size



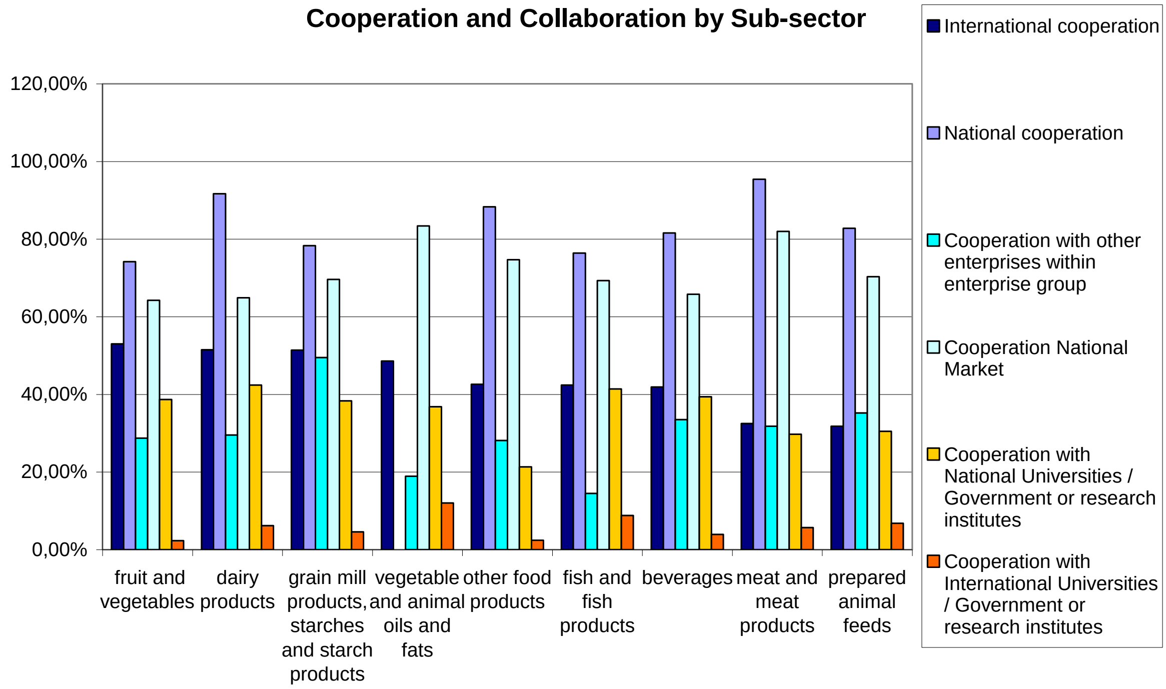
Source: Eurostat CIS4

Large firms thus show the best capabilities for cooperating with research institutions and universities, especially internationally, which gives the clearest connection to innovation-related activities. Especially in this area small firms are virtually excluded (a share of 1%). But small firms seem to show a large interest in national cooperation on a general basis and especially with markets, which could also be related to their comparatively large funding support by regional authorities.

As in regard to sub-sectors, all sub-sectors show the highest scores in the area of national cooperation, whereas here the manufacturing meat products that otherwise shows generally low innovation-related scores has the highest share. For all sub-sectors, cooperation with international universities and research institutes is low, below 10% with the exception of manufacturing of oils and fats that scores slightly above 10%.

In general the findings provide a picture of good market collaboration but less activity in regard to collaboration with research institutes and universities, especially on an international basis. Perhaps the embedding of firms into R&D clusters could improve this situation and provide easier access to cooperation opportunities.

Figure 2.4 Cooperation and collaboration by sub-sector



2.3 Clusters and networks

Clusters can form out of different reasons and have different characteristics. Michael E. Porter (1998) defined clusters as “geographically proximate groups of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities”. Proximity is necessary for sharing resources and knowledge and the generation of spill-over effects. But solely spatial proximity is not enough. For cluster effects and knowledge-creation processes to occur it is necessary to establish interactions. Linkages need to focus on a common goal and finally there has to be a critical mass of interacting participants (ibidem). The close proximity of thematically related industries has many advantages like a shared infrastructure, easy access to human resources and know-how from universities and innovative R&D institutions and a nearby pool of specialized suppliers and partners. Clusters allow for a better communication between research, the industry and customers, cost reductions and have a more stabilizing effect for employers. Clusters also increase competition, thus providing growing incentives to innovate.

Ketels (2004) listed four critical elements of clusters: proximity, linkages, interactions and critical mass. How clusters function and operate can be further explained by the typology of Iammarino and McCann (2005) who distinguish between a pure agglomeration model, an industrial complex model and a social network model. *The pure agglomeration model* is characterized by economically weak, “atomistic” companies that continuously change co-operations. The cluster is mostly defined through the geographical presence of a number of firms belonging to a specific sector. The mutual benefits of clustering are very marginal and competition is high. Such clusters often form due to external circumstances like the proximity to necessary raw materials or infrastructures. *The industrial complex model* is characterized by hierarchical structures and stable and long-term relationships between firms, mostly large firms and their suppliers or service providers. Entry and exit costs are high and the main advantage of clustering lies in the reduction of inter-firm transport and transaction costs. These cluster types are mostly encountered in mature industries like steel or (traditional) chemicals. *The social network model* is characterized by low hierarchies and mutual trust relations that prevent opportunism (cf. Granovetter, 1973). Because of modern information and communications technologies and the growing importance of non-physical resources, i.e. knowledge and information, spatial proximity is not a necessary condition for co-operation anymore and even far-away and virtual co-operation is possible. But proximity and face-to-face contacts still represent an important factor to reinforce mutual trust relations (cf. Shire et al., 2007). The network model is especially suitable for SMEs.

The cluster mapping of the European Cluster Observatory uses industrial concentration and relative employment shares as a basis for identifying clusters. In total 148 food and drinks clusters have been identified by the European Cluster Observatory database (state of play March 2009). With 25 food clusters, Germany is the leading country in terms of numbers, followed by France with 19, Poland with 18 and Spain with 11 food clusters. Turkey is also included with 12 identified food clusters. With 10 out of 25 clusters, Germany also has the largest share of high innovation ratings. The high-innovation clusters can be found in Germany (10), France (4), UK (4), Belgium (1), Denmark (1) and Austria (1).

With respect to exports, clusters in Denmark, Ireland and the Netherlands are the only ones rated as very strong. France, Germany, Lithuania and Poland have clusters rated with 3 stars, which means that that have already reached critical mass in size, specialization and focus. The most successful clusters seem to be in France, Bretagne (3 stars, strong exports, medium innovation) and in Southern Denmark (very strong exports, high innovation, 2 stars).

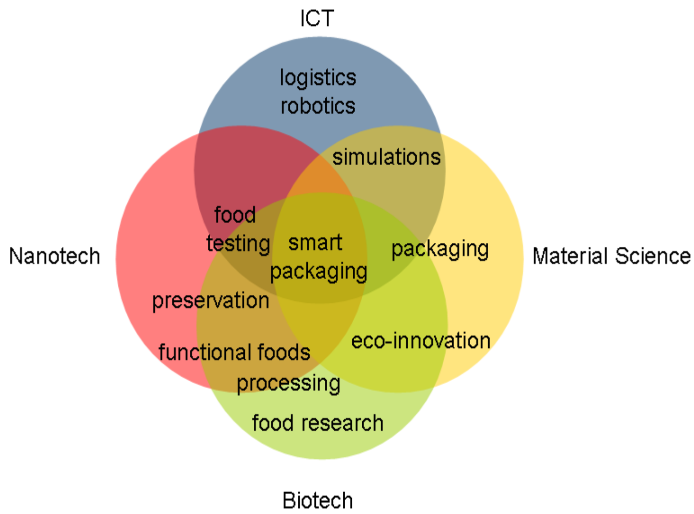
The future role of clusters

Clusters represent a balancing act between co-operation and competition which has to be maintained to spur innovation and competitiveness. It might be necessary that future clusters go beyond the traditional industry-lines and research areas – something that may at first sound counter-intuitive when thinking about industrial clusters – to enable more interdisciplinarity and provide complementary competences. The emphasis of clusters may shift away from the “particular field” as in the definition by porter as “geographically proximate groups of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities” (Porter, 1998) towards the greater emphasis of co-operation as it is being expressed in the cluster definition by Chiaroni and Chiesa as ‘‘a geographical concentration of actors in vertical and horizontal relationships, showing a clear tendency of co-operating and of sharing their competences, all involved in a localised infrastructure of support’’ (Chiaroni/Chiesa, 2006).

A next step could be the further analysis of advantages gained through interdisciplinary clusters and the effects of interdisciplinary exchange on innovativeness within different sectors. Since different industry and research sectors are more likely to represent complements than competitors it can be assumed that the threshold for their formation and co-operation may be lower and mutual benefits higher.

According to some leading thinkers in foresight, interdisciplinarity is seen as the key factor for innovativeness and an enabler for tackling Grand Challenges. Therefore especially inter- and multidisciplinary clusters with leading firms and institutions from different areas in close proximity could greatly contribute the improvement of innovativeness of a single sector as well as to the overall improvement of a region or country.

Figure 2.5 Convergence and cross-cutting issues



Source: TNO

3 Sectoral innovation futures

Many innovations in the food and drinks sector depend on further developments being achieved outside the sector, such as biotechnology, ICT, automation, nanotechnology, neurosciences and material sciences. These are very likely to bring about new ideas and solutions for healthier foods, improved food safety, cost reductions, innovations in food chain management and warehousing and a generally better understanding about nutrition and the relation between food and drinks consumption and human health.

The research areas mentioned above are constantly progressing and will continue to do so in the future. It is even expected by some that the progress in these areas might become more interdisciplinary and through “intellectual cross fertilisation” even accelerate, which could generally lead to radical changes or disruptive effect in some areas. New scientific and technological potentials are not only affecting products but also regulations, laws and societal issues. In this respect the main issue to be taken into account in respect to food and drinks rather relate to societal, political, legal and economic factors that could hamper fast progress. It has to be said, however, that the technological progress within the next 20 years could also easily get overestimated since many emerging science and technology fields are quite new and complex and their real impact – also in terms of consumer take-up and trustworthiness - is currently hard to assess. Whereas the previous section has described more general drivers, the following will provide an overview of some specific technologies and driving factors as well as barriers.

The spectrum of technological possibilities for innovations in food and drinks products and production is large, but not all suggestions are being perceived with the same acceptance by consumers, interest groups and policy-makers. Some innovations like the production of healthier foods and drinks, fat reduction, the usage of less conservatives and additives that are considered harmful as well as environmental concerns are challenge and problem-driven. Other innovations, however, are rather driven by technological possibilities as it is for example the case with the application of nanotechnology or genetically modified ingredients in food and drinks processing. Here demands are assumed since the technologies are expected to solve certain problems or improve certain aspects of foods, drinks and their production (e.g. improve taste, consistency or shelf-life), but expert and consumer concerns over potential health risks make such innovation ideas uncertain in regard to successful future market introduction. Another example is medicinal food that goes beyond functional food, which is likely to become technologically possible by under current conditions would lead to legal problems. Additionally there are also innovation proposals that are suggested as solution to certain challenges and problems like utilising abundant insect proteins or developing cultured meat that currently do not seem to be too popular with European customers.

3.1 Evolution of the sector – past and recent trends

Although early forms of food processing date back to ancient times where raw agricultural materials were modified simple by technical means (e.g. drying, salting, fermenting), the modern, industrialised food and drinks manufacturing of the 19th and 20th century has mainly developed within the military context. The real boom in large-scale manufacturing of foods and drinks appeared during the 1950s and 1960s. This time experienced much experimentation and innovation in food and drinks, but also in many other fields of science and technology. The so-called “TV-dinners” and ready meals were introduced in 1953, the artificial sweetener aspartame was discovered in 1965, and the first microwave ovens for home use were introduced in 1967. The soft-drink industry was born in the 1960, slowly replacing the traditional soda stores and vendors. This shows how developments in the food and drinks industry already then closely related to developments in other sectors (retail, restaurants) as well as new technologies such as TV-sets and microwave ovens, and welfare driven life-style changes like the rise of fast food and ready meals.

But these developments also brought about societal criticism on new food and drinks production methods and techniques as well as newly invented ingredients. The case of saccharin, one of the artificial ingredients, serves as an example. After being introduced in the 1960s, ten year later in the 1970s the US FDA already considered banning it again because laboratory tests have shown that high doses of saccharin increased the incidence of urinary bladder cancer in rats. The ban did not go through, but a warning label was required. This was also due to the fact that the doses used in the tests were high and it remained controversial if the results of mice were transferable to human physiology. Later developments, such as the introduction of genetically modified organisms (GMO) and more generally the rise of biotechnology are proof of new and innovative developments, but have also led to societal concerns. Genetic modification in crops which started in the early 1980s (the first recorded GMO plant was an experimental tobacco plant in 1983) as well as animal cloning have led to controversies and even bans. The latest developments in nanotechnology for food packaging give rise to similar reactions. At the same time, biotechnology – and perhaps even GMO - can provide us with more predictable processes, better primary production, new inspection methods and healthier, safer and sometimes even tastier food.

Criticism about the ‘industrial’ image of food and drinks (industrialisation) has grown since the 1980s and has coincided with increasing attention towards the environment (‘green’ movement) and sustainability issues, health and quality over quantity (slow food as a reaction to fast food). It also signifies the beginning of the current trend towards organic, natural, fresh and unprocessed foods and drinks, and an increasing focus on local and fair trade products and ethical concerns by consumers. Whereas at some time the optical appearance of food – symmetric form, beautiful colour and flawlessness – has been highly regarded and thus has been enhanced by food colouring, additives and even GMO, today too much ‘perfection’ makes many consumers suspicious by indicating non-naturalness.

Health concerns, and more particularly current challenges such as obesity, other diet-related illnesses, allergies, chronic diseases and aging have also stimulated the emergence of new generations of functional foods and drinks. Thus, Consumer preferences in no way point towards the same direction. Mainstream trends such as an increasing consumption of convenience foods like pre-packaged and processed foods and drinks, easy to consume products (e.g. “TV dinners”), snacking, fast food, take-away food and out-of-home consumption are likely bound to continue, whereas also here health consciousness may get bigger. Fast food chains like McDonalds, for example, are increasingly advertising with a more health and “natural” image (e.g. no additives in their beef products, salads on their menu, providing calorie tables and “going green”). Other choices, especially in the context of active lifestyles, enjoyment, wellness as well as environmental and social concerns have – as a result of steadily rising incomes – also become important consumer trends that importantly affect food and drinks sales and consumption.

3.2 Emerging and future drivers of innovation between science & technology and market demand

Science & technology drivers

Future advances in science and technology coming from areas outside the food and drinks sector, even though some are related to the industry, will most likely have a continuing strong impact on the development of the sector. A real science-based analysis of food and drinks on a fundamental and molecular basis has only recently been made possible through improving insights in biotechnology, genetic research and the availability of the necessary computer power and laboratory equipment. Many technological and scientific challenges for the improvement of food and drinks products still remain, but it is likely that science will gradually find solutions to them.

The food and drinks manufacturing industry profits a lot from research and development that is being conducted in (emerging) science and technology (S&T) fields like chemistry and physics (e.g. in regard to separation techniques), molecular bio(techno)logy, medicine, ICT, material sciences, nanotechnology, robotics (for processing and automation) and even neurosciences. A very important contribution comes from the growing interest in and growing understanding of the workings of the human body and biological systems in general (e.g. in regard to food spoilage and preservation).

In the following paragraphs a number of recent S&T developments which act as drivers are described.

Epigenetics, nutrigenomics and neurosciences

An improved understanding of biological systems and the human body matters for the future development of the food and drinks industry. With a growing understanding of genetics, new scientific research is showing that environmental factors like the intake of certain foods and drinks can in fact have influences on gene expression, i.e. influence if certain gene may become active or not. Such insights could lead to new forms of nutrition engineering or even change the way we are thinking about the role of food and drinks in our lives. Research going on in genetics, epigenetics, metabolomics (science about metabolism), proteomics (science about the function and structure of proteins) and similar areas have already created the research field of nutrigenomics, which studies the effects of nutrition on genes and metabolic functions. A very important contribution that makes such research possible comes from advances in computer sciences that bioinformatics which enable the necessary complex calculations and simulations (e.g. in regard to protein-protein interactions).

New and cheaper possibilities for gene mapping and molecular biology are already emerging as the most computing-intensive tasks in human history (Forbes, 2009). Dropping prices and speed increases in genome sequencing – which might come for 1000 US$ around 2014 – will also be an important basis for possible personalised foods and drinks that are matched to an individual's genetic makeup. However, scientists are currently only at the beginning of understanding the real implications and meanings of sequenced genome data. Personalised functional food, although not impossible, is likely to take some time until reality and economic feasibility.

Also research in neuroscience could provide the basis for the development of new foods aimed at inducing specific neuronal states like happiness, calmness or improved concentration achieved with the help of specific ingredients. Researchers are, for example, unravelling the neurochemical effects of chocolate and try to give a scientific basis to so-called "mood foods".

It has also been suggested in research that different combinations of foods and drinks can influence how nutrients are being utilised in the human body. This could lead, for example, to science-based combinations of items in ready meals, leading to healthier overall compounds. Such insights could also lead to new forms of marketing innovations, e.g. by providing consumers with science-based recommendations for side dishes, vegetables or spices based on their choices being made while shopping (e.g. the nutrients of this fish are best digested when eaten together with these vegetables and spices) or composing ready meals based on science.

Miniaturisation, biotechnology and nanotechnology

Humans are able to observe and manipulate matter on an increasingly small scale. The micro-level has been left behind; to enter the even smaller nano-scale refers to objects of a size close to 1-100 nanometres (1 nanometer being one-billionth of a meter; 1 micrometer equals 1000 nanometres). Our increasingly better understanding of molecular biology and modern biotechnology also leads to better knowledge about the mechanisms behind food contamination and spoilage and also enable new ways to improve preservation and food safety. So-called lab-on-a-chip modules, which combine technologies from ICT, nanotechnology and biotechnology, allow for fast and mobile food testing for a variety of pathogens, bacteria and contamination.

Genetic engineering principally allows for the creation of plants (and animals) with some optimised characteristics like increased vitamin level or higher yields, or enable possibilities to get rid of allergens. Even totally new or modified organisms could be created that may be used to fight off harmful bacteria or produce functional ingredients.

As it is the case in other fields of material sciences, nanotechnology also opens up new possibilities for the food and drinks industry. They range from improvements of texture over targeted nutrition and flavour enhancement through "nano-encapsulation" to smart packaging for more safety. Nanotechnology can be used in food processing (e.g. nano-encapsulation of nutrients, nano-emulsions), food packaging (e.g. barrier materials, antibiotic packaging, smart packaging) and sensor systems for food safety testing. Although operating on the nanometre-scale is nothing new in food production, many consumers and consumer advocacy/protection groups are concerned about "nano" in food. Since some elements really show different reaction characteristics on the nano-scale in contrast to larger particle and compound sizes and nano may enter the blood stream and cross the brain-blood barrier more easily, the issue requires more scientific evaluation.

Material sciences and intelligent packaging

Especially the area of food packaging benefits from general advances in material sciences. Anti-biotic materials, heat/cold resistant materials, eco-friendly packaging and even edible packaging have already been developed or are under development. Edible packaging may pose some problems in regard to hygiene if really intended to be eaten, but at least such products will put no harm to the environment since they are digestible and biodegradable.

Also in line with food sciences being understood as a kind of material science, technologies used in modern material development and testing like simulations might also be of use for food and drinks manufacturing. For example, the raw materials coming from farming are always different in composition, which necessitates changes in processing and ingredients to yield constant and satisfactory results. Computer simulations could be used to analyse and predict the behaviour of ingredients, physical and chemical properties and even the spread of micro-organisms.

Automation, robotics and ICT

As robots are becoming increasingly flexible, versatile and “intelligent” as well as cheaper, they are also getting much more attention from the food and drinks manufacturing industry. According to statistics from the World Robotics Report 2008, the food and drinks industry is currently responsible for major increases in demands for industrial robots (World Robotics, 2008). Beside the indirect contribution of ICT in regard to calculations in the bio- and nutritional sciences, ICT technology is becoming an important part of logistics (e.g. in transports and fast-food-management) and food chain management. RFID-technology allows for consistent traceability and fast product identification and is also part of smart packaging concepts.

Demand-side drivers and emerging product markets

The Strategic Research Agenda 2007-2020 of the European Technology Platform on Food for Life addresses three major action points (‘key thrusts’) (ETP, 2008: 5):

- Improve health, wellbeing and longevity
- Build consumer trust in the food chain
- Support sustainable and ethical production.

The key action points reflect the major issues that are being addressed by the European food industry and underline the need for developing new processes, products and tools in order to improve competitiveness. They are defined in anticipation of today’s and tomorrow’s consumer and societal preferences.

In the coming years the familiar, more or less predictable body of mass consumers of the present will more and more turn into smaller, narrowly defined target groups each with their own agenda, interests and preferences. The future is likely to consist of consumers that will increasingly demand everything at the same time, but also more tailoring to individual needs (e.g. Martin, 2007).

The figure below represents a number of demand 'attributes' (dimensions) each of which pose and will continue to pose challenges for the food and drinks industry.

Aliments against ailments - health consciousness, disease and ageing

People are expecting more from their food and drinks than just satisfying their hunger and thirst. Food and drinks are seen as an integral part for improving health and wellbeing. Consumers seem to get increasingly health conscious – and at least more concerned - about their intake of foods and drinks. This can be observed not only in the growing interest in functional foods, but even more in the current trend towards natural and organic foods and scepticism about synthetic ingredients.

As the life expectancy of people increases, so does the probability of age-related diseases and ailments. Since the bodily constitution and metabolism of elderly people change, other kinds of nutrition and nutritional balances are required for this age group. This has already led to the introduction of a new profession: gerontological nutritionist. Food companies are also already reacting towards this new and growing set of consumers. The interest is also growing on the "preventative". Much scientific research is being conducted in the area of identifying foods and ingredients that can slow down aging-effects like cellular damage or physical and mental degeneration. However some claims being made are not based on sufficient and/or accepted scientific evaluation. The current striving for improving "healthy aging" is a big driver for food innovations. Still, the huge problems of obesity and other diet-related illnesses tend to increase, even to such an extent that according to some the steady rise in life expectancy may come to an end (e.g. Martin, 2007).

Currently, however, especially fast-food chains and fast-food products like pizza as well as snacks are heavily criticised as a reason for obesity, imbalanced nutrition and so-called "civilisation illnesses" like type-II diabetes. Fast food chains, especially McDonald's, have started to react and are now advertising with being more health conscious, offering salads and presenting themselves as caring for the environment. Another reason for obesity may also lie in the fact that most people in today's post-industrialised countries need fewer calories due to their work that requires less physical activity and burning of calories. Besides this, the industry is not responsible for the consumer's eating and cooking habits.

The interest in healthy eating and drinking is huge and currently there exists a wide variety of partly contradicting advices concerning this topic. Science-based approaches towards more healthy foods and drinks could represent a big contribution. To meet this goal, a better understanding about the relationships between nutrition and health effects is necessary. Progress in modern bio (techno) logy is of great importance.

Financial and other incentives that stimulate healthy lifestyles and ditto consumption patterns get increasing attention. As an example serves VGZ, one of the largest Dutch health insurers, who since 2005 reimburses clients who use Unilever's cholesterol-lowering Becel pro-active products, because of the products' beneficial health effects (Unilever, 2005). Scientific research and evidence play an important role in such bonus/reward schemes. This example reveals some underlying and interesting developments that might become even more common in the future: the blurring border between functional foods and medicine, the scientific trust in functional foods and new alliances between food and drinks manufacturers and other sectors (e.g. health insurers). Similarly, the German health system reform envisages health insurance bonus systems for adopting a healthy lifestyle, while non-compliance, for example by diabetics refusing doctor's advice, will be punished by means of supplementary payments (e.g. Müller, 2007).

Food allergies are on the rise and can have grave limiting effects on quality of life. As more and more customers are experiencing food allergies or food intolerance, the food and drinks industry has to react by adjusting the choice of ingredients, labelling or finding ways to engineer foods and drinks that do not contain allergens (if no medical treatment for allergies can be provided).

Food safety and consumer confidence

One of the most important factors for consumers is food safety. Food scandals, the selling of spoiled food and contaminations are affecting consumers and the food industry alike and lead to consumers loosing trust in the industry and retailers. The call for safe food is loud, due to food scares and scandals of the past. Globalisation and world-wide sourcing increasingly call for better tracking and tracing by the industry as well as improving health and safety monitoring and control. Independent governmental agencies (viz. the European Food Safety Authority (EFSA) and national agencies) play an increasingly important role in securing the safety of food and drinks. This requires the drawing of clear and transparent roles and responsibilities, alongside with a system of appropriate checks and balances.

Improvements in fast and real-time testing and monitoring "from farm to fork" can be realised with a combination of ICT (e.g. RFID tagging), nanotechnology (smart sensors on packages), biotechnology and material sciences through improved preservation, better packaging, smart sensing and testing and global traceability (tracking and tracing) and food chain management. Important milestones have already been set, but even more can be done, especially at a global scale.

Safety is very much a matter of organisation within the value chain. Retailers have taken much of a lead here and have been very active in setting up integral chain management (e.g. the EurepGAP label – European Retailer Produce Good Agricultural Practice, recently transformed into 'Global GAP' – Global Good Agricultural Practice). Since retailers are the last actors in the food and drinks value chain, they are very dependent on the input and quality of the food industry, agriculture (especially in regard to raw fruits and vegetables), safety analysis and logistics (e.g. correct storage of products). Food scandals or other kinds of consumer dissatisfaction with certain products are affecting retailers to a high degree, since many customers regard them as responsible.

Therefore the future might make food safety more challenging, especially in face of globalisation and complex food chains, but technology can also help to improve food safety within complex constellations, e.g. through better tracking, surveillance and testing.

Ethical concerns and sustainability

Environmental pollution, the unrestricted use of scarce and non-renewable resources such as oil and gas and – hence – sustainability are rising societal and consumer concerns, not only in Europe but worldwide. Ethics and sustainability – the future of mother earth – go hand in hand. Ethical concerns also apply to animal rights and to the consumption of animal products. The awareness about animal rights is growing, leading to consumer criticism about industrial farming and the use of growth hormones and antibiotics in mass animal production. Many consumers are choosing more “ethical” products like eggs and meat from free-range animals, “organic” and “fair-trade” products. A growing number of manufacturers are already advertising with labels that indicate the utilisation of renewable energy sources (e.g. wind, solar and biomass/food waste) being used for production, following the general trend of displaying the manufacturer’s environmental and ethical considerations (e.g. in regard to animal keeping or fair trade) in form of labels..

Sustainable food production has innovation potential, especially where production methods and resource management (renewable energy, energy efficiency, food waste management, water management, etc.) are concerned.

Convenience food and take away food/home delivery

Convenience and health are probably the two biggest food and drinks trends; they are at the same time seemingly contradictions. The choice for convenience food is rooted in changing life-styles, busy lives and lack of time. The popularity of convenience food also relates to the diminishing size of the average household (two and one person household). The term convenience food applies to ready meals, conveniently packaged and processed foods, snacking and snatched meals, and eating out in canteens, catering establishments and restaurants. However, due to the financial crisis, eating out is on the decline because of the higher costs. ‘Grazing’, eating on the move and ease of container-opening for children and the elderly are all demands that, when being met increase the convenience of food consumption. Technologies for convenience foods focus on: easy to handle, time saving, ready-to-eat and heat-to-eat (ETP, 2005).

Potential future demand may develop into the direction of high value-added convenience foods – in particular functional foods that are designed to meet the nutritional and health needs of every individual. Another future direction is convenience products made from fresh and healthy food. Sustainable and healthy fast food could become an innovation topic.

Price consciousness, affordability and value for money

A considerable share of consumers - and customers in general – acts price conscious in regard to food and drinks products. The financial crisis has caused at least some customers to turn away from more expensive “natural”, “organic”, “healthy” and “ethical” food as well as high quality food towards cheaper conventional products and fast food. The crisis does not only affect the food consumption patterns of the lower income strata of society. Even though the food industry is typically much less affected by ups and downs than other sectors (European Commission, 2009), uncertainty and falling consumer confidence increases the price sensitivity of consumers, with possible demand shifts towards hard discounters (e.g. Aldi, Lidl).

Discount retailers have already started to adapt towards the consumer wishes of inexpensive quality and health and even discounters offer “organic” and natural foods, often presented as store brands. More generally, it remains questionable how much additional money consumers, especially those with lower income, would be willing to spend on functional foods and health innovations. Studies also suggest people from lower-income strata and less education are more prone to obesity, imbalanced nutrition and resulting health problems. A major reason for this is that people with less income tend to buy foods that are cheap and satiable, but contain more fats, sugars and salt and less valuable nutrients. If the expensive ‘high-tech’ food or ‘organic foods’ show significantly positive health effects as compared to cheaper products, this could contribute to a divide-like situation between the wealthier and poorer strata of society that effects life expectancy, health and wellbeing.

The profit margins of the food and drinks sector are generally low throughout the whole food chain and market power within the chain is a serious issue as the example of the recent milk-price drops and milk-farmer’s protests show. Most food and drinks products are being sold through stores and supermarkets that seek new ways to attract customers though appealing products, shop designs and a good shopping atmosphere as well as reducing costs. Cost reductions can be achieved through more efficient warehousing, supply chain management, automation or through the introduction of private labels (i.e. retailers' own store-brands). Retailers and large supermarket discounters have introduced private labels as an alternative to the more expensive and established international renowned brands. Many of these brands relate to quality and ecology-oriented or natural products. Automation, especially in warehousing, can lead to substantial cost savings. The 1 Euro-shops, for example, can only sell for such cheap price because of large-scale rationalisation and automation in warehousing and logistics (besides cheap product manufacturing in China and Eastern Europe).

Taste

Taste can be considered as one of the most relevant properties of food when it comes to consumer choices. However, since taste sensitiveness and preferences are highly individual but also dependent on culture and habit, this dimension is difficult to objectively quantify. There may also be trade-offs between taste and other dimensions of foods and drinks like price and health. Researchers like Harvard’s Daniel Lieberman are suggesting that people’s preferences for what is nowadays considered unhealthy food like too much (saturated) fats, sugars and crispy foods (which can indicate freshness as contrasting to less fresh items, e.g. in vegetables) is rooted in human evolution and pre-modern living conditions where a preference for energy rich foods, fat and sugar was an advantage for survival, conditions which however do not apply to the lifestyle in (post)industrialised societies.

Thus, from an evolutionary/anthropological perspective, taste preferences are related to assessing the nutritional value and safety of food items found in the wild. Humans prefer sweet food because it promises fast energy intake and tend to dislike bitter food because many toxic items are bitter.

Looking at it from this perspective and also considering neuroscience, biological, cultural and neurological factors play an important role in regard to taste preference.

In modern (post-) industrialised cultures, taste has mostly lost its function for distinguishing between edible and non-edible items and, as already mentioned, some parts of the human evolutionary heritage are not suitable for modern living anymore. However, taste is still a very important criterion for food choices, whereas the cultural dimension of tradition - as well as experimenting with the tastes of other cultures – has become a major factor for gastronomy and the industry. This can be seen through the observation that century old food traditions (e.g. in confectionary, beer, wine, meat specialities) are still valued and surviving with their traditional manufacturing methods and ingredients despite modernity. Also recipes from around the world are entering supermarket shelves dominated by industrial products. If taste and preferences are tied to specific production methods and ingredients that are not to be altered due to tradition or intellectual property right/trademarks, innovation is of course not really possible, except for indirect areas like preservation, packaging or marketing.

However, taste preferences can conflict with health as well as innovation. The problematic relation to health does not only stem from the human evolutionary/anthropological heritage but can also lead to disputed (but within the EU well regulated) ingredient choices in the context of industrialised and budgeted food production like certain artificial flavours and flavour enhancers. Some innovative future ideas like nanotechnology-based “programmable food” also deal with experimentation of taste, whereas such ideas are currently also considered with scepticism and would face problems with approval.

Modern preservation methods, especially non-thermal ones are concerned with keeping the taste of foods intact. Other preservation methods are exploring the utilisation of spices (e.g. rosemary, wasabi, parsley) that add good taste and at the same time serve as natural preservatives. This is in so far interesting as here innovation can be viewed from a different perspective, i.e. preserving and maintaining the taste of naturalness of food that is also related to the increasing health consciousness of some consumer groups.

Molecular gastronomy, i.e. focussing on the scientific biochemical and physical dimension of cooking, a trend that has gained interest over the last years, has been inspired by methods of industrial food processing but is also being taken up by the industry. Other food “sub-cultures” like the “slow food” movement are intentionally opposing modern trends of fast, mass-produced and uniform food and emphasise taste, indulgence, health as well as traditional and regional specialities. If regarded as a counter trend to the mainstream and thus as something new, “slow food” could be seen as an innovation, whereas not in a real technical sense but rather from the perspective of lifestyle, economic alternatives (strengthening regional and rural areas) and marketing.

Taste, of course, remains central to food but the relation of taste to health and innovation can be ambivalent. Humans tend to prefer tastes related to generally less healthy food in modern contexts (e.g. fat, sugar), but also associate taste with health and healthy eating (savouring the taste) as in the slow food movement. “Artificial tastes” in budget food production cause controversies and exotic tastes can awake curiosity but also rejection. Innovations can contribute to better taste preservation (e.g. advanced preservation methods) and even create totally new taste experiences as in molecular gastronomy and some envisioned future nanotechnology possibilities.

3.3 Sector scenarios

Main trends and drivers form the backbone in formulating five future scenarios. The following trends have taken as 'fixed' for all scenarios:

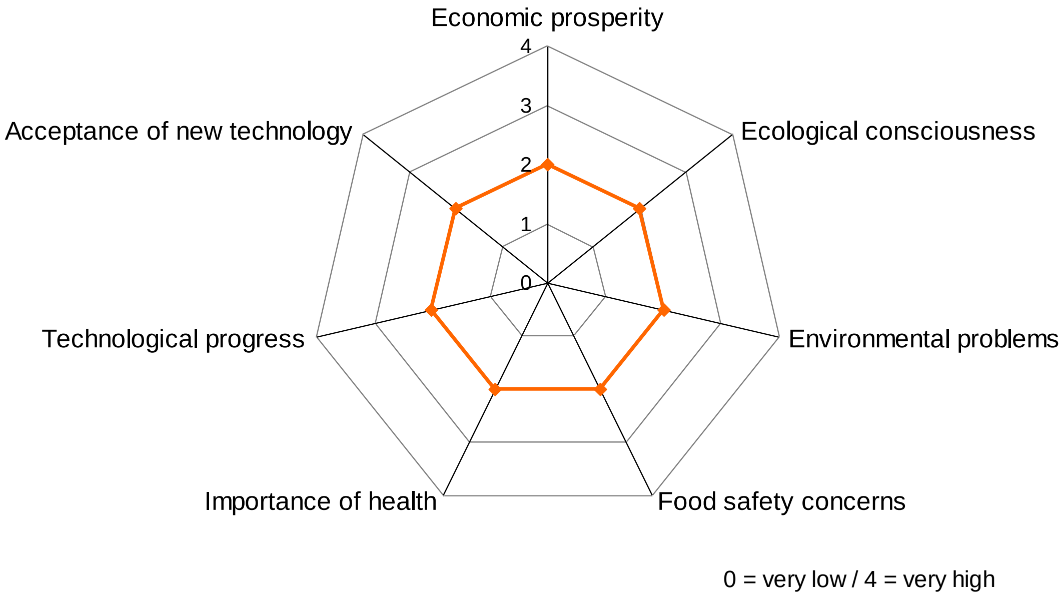
- Increase in global population - 6.9 billion in 2010 to 7.6 billion by 2020 (UN figures)
- Decline of population in many EU countries due to lower birth rates
- Increasing life expectancy in EU countries (aging society)
- Increases in scientific and technological knowledge and possibilities.

Differences between the scenarios are supposed to follow from different assumptions on:

- Economic prosperity
- Ecological consciousness
- Environment / global warming
- Food safety
- Health
- Innovation and technological progress
- Acceptance of new technologies and innovation from a legal and individual consumer perspective

The first scenario, labelled 'business as usual' serves as a baseline and actually depicts the current situation of food and drinks production with the scores for the different dimensions (cf. graph-diagrams) set to an intermediate position. The diagrams of the other scenarios should be read relative to the baseline ('business as usual'). Also the developments of the different scenarios are based on current trends in the sector, whereas in each scenario different dimensions are being highlighted.

Figure 3.1 Scenario 1: Business as usual (base-line or reference scenario)



Drivers and framework conditions: In this scenario, different drivers are relevant and competing with each other, whereas none of them will be really dominant. New developments in science and technology are bringing about new possibilities, whereas safety concerns, scepticism of some consumers about novelties in foods and drinks, legal and regulatory issues as well as high costs for innovation and budgetary constraints of consumers are countering some forms of “radical innovation”. Food and drinks products thought to be healthy and sustainable are still more expensive than average products. Thus two directions are co-existing: cheap food produced en masse with the help of further efficiency strategies still represents a less healthy alternative, while on the opposite end of the market more expensive organic and functional foods and drinks are being offered, which are considered healthier but also more expensive. In general, this scenario is also rather characterised by control, i.e. good practices in food safety are mostly due to legal obligations and controls. Innovation strategies are varying where some are putting more emphasis on efficiency and cost reductions, others focus on health, ecological factors or producing novelties.

In this scenario the gap between population groups with higher incomes and higher education vs. lower income and lower education will remain and will also be reflected in food choices, supporting high-end as well as budget products. The overall economic situation is characterised by moderate growth thus leaving only limited resources for food and drinks innovations and only limited support for overall research, development and innovation thus leading to only moderately-paced technological progress.

Characteristics of the industry and products: In this scenario the food and drinks manufacturing industry is characterised by a rather high degree of inertia and there will not be many significant changes in the future. The industry will remain a mix of inexpensive conventional production (“industrial food”), more expensive organic products and a segment of more innovative functional foods and drinks, especially aimed at sports people, young adults (energy drinks) and elderly. Although healthy eating is promoted, the ideal and reality look quite different. Whereas some people are quite concerned over healthy nutrition, another large share of the population either can not afford healthier choices or does not care enough due to various reasons (e.g. lacking knowledge, lack of time). Even within the segment of people who care much about healthy eating, approaches differ much and range from preferring organic and natural choices over vegetarian diets to opting for functional food or compensating unfavourable eating habits through supplements.

Whereas the product palette and the production methods do not change much, food safety gets increasingly important as many research and development efforts are put into this goal and legal requirements are getting stricter. Modern technology and innovations in biotechnology (e.g. LOC-technology), nanotechnology (smart labels) and ICT (e.g. RFID-based food chain management) are very important and are being constantly improved, but nonetheless mostly aim at the non-food parts of the food chain (e.g. packaging, testing and control). There will be a co-existence with more traditional food and drinks manufacturers alongside some functional food innovators. Consumers, the food industry and retailers are the drivers for the development of better and more reliable testing and firms as well as retailers will experience high losses if food scandals occur.

In general, many producers are striving to make currently unhealthy food (e.g. fast and 'junk food') healthier and fight obesity and other "civilisation illnesses", partially driven by regulations. Major scepticism about highly modified and "technologized" foods and drinks remain and there exists a tendency towards thinking that organic and natural foods and drinks are a generally healthier choice. Also many traditional foods remain highly popular, unchanged products still generate high turnovers and many new introductions will not become popular. In general, the industry and products are characterised by a wide diversity of choices. Some products however remain quite short-lived while others become well established. This scenario opens the possibility for greater fragmentation of the industry and the birth of new SMEs; while on the other hand, acquisitions by large multinationals can also become more common.

Possible innovations include:

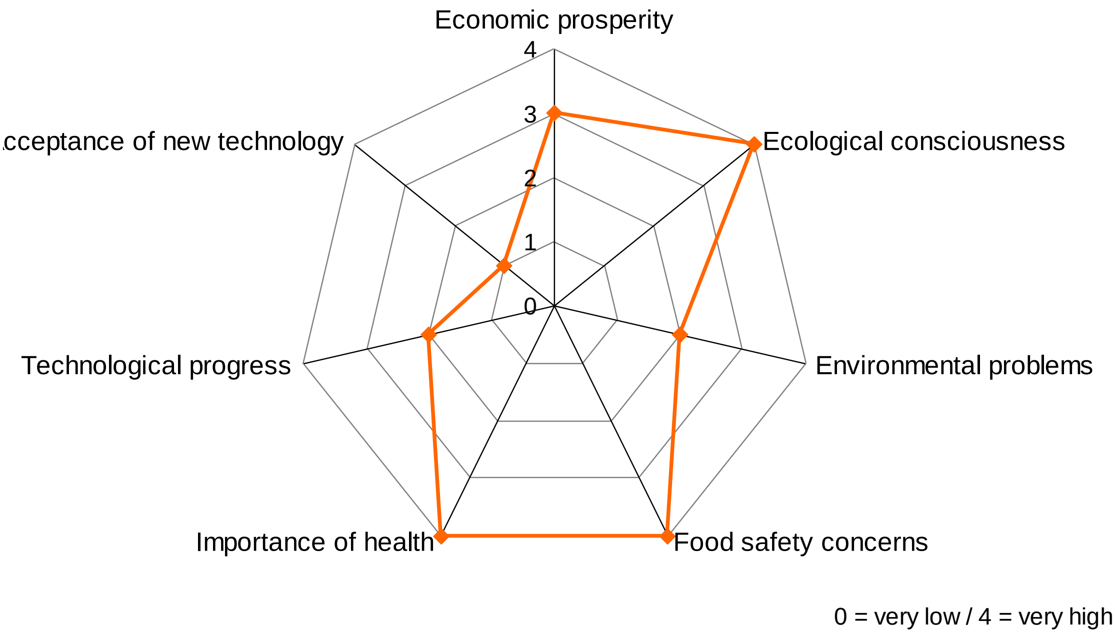
- New lifestyle products
- Functional foods (mood, cosmetic, anti-aging)
- New international and exotic products or "domesticated" foreign products
- Growing share of organic foods
- Growing share of "light" and calorie-conscious products
- Food for the elderly
- Food for allergic consumers
- Healthier fast and "junk food"
- New convenience food, snacks etc.
- Opportunities for experiments.

Winners: ICT and testing, innovative biotech and nanotech companies, regulators, no real winners

Losers: No real losers

Potential risks, barriers and challenges: This scenario leaves us with a highly fragmented market where some innovation takes place alongside consumer choices for traditional and unchanged products. There is no clear direction towards a specific tendency which makes planning and innovation strategies for the industries difficult. One major driver for innovation can be regulations that prohibit certain practices and ingredients or set limitations and standards. Consumers will likely rather stick to their habits which also causes industries to rather refrain from experiments. The food and drinks sector will only slowly change and significant improvements can not be expected fast. On the positive side, the different interests cause some kind of balance between different forces where opposing practices like highly rationalised factory-style food and drinks production co-exist alongside production methods that strongly focus on ecological sustainability and fair trade. The large diversity of products and approaches does not lead to “monocultures” and thus may contribute to a broad affordability of food products and high flexibility towards changes.

Figure 3.2 Scenario 2: Going natural



Driving factors and framework conditions: This scenario is especially shaped by drivers related to consumer interest which shape the trajectories of research and technology. Although technological and scientific knowledge about genetic technologies, nanotechnology-related possibilities, cheap food production etc. exists, consumers are very sceptical about their benefits and prefer not to choose them. The current trend of increasing customer interest in organic and natural food is continuing and more and more people prefer products that have been grown and processed with natural/organic ingredients (as legally defined) or that have been only minimally processed. On the other hand, consumer trust in large industries and large-scale food processing and factory farming declines. There is a general belief that organic/natural products are also safer and healthier and a more ethical choice that is shared by many consumers ranging from environmentally active persons to people very much concerned over a healthy extension of their life span. Organic and natural food has become the major standard in EU countries with comparatively low populations and even discounters have adapted to this trend and offer more inexpensive products.

The general economic situation is rather positive in this scenario and is also reflected at individual financial prosperity and a large number of people is able to afford more expensive foods and drinks. In general it is also more quality than quantity that counts in regard to consumption. There is a wide spectrum of technological innovations in food processing that is compatible with this scenario like increasing efficiency in organic farming with the help of GPS and soil analysis-based precision farming and advanced indoor farming. Also natural and non-chemical (e.g. physical like high pressure) preservation methods are gaining interest and support.

Characteristics of the industry and products: As smaller companies and local producers are being favoured by a considerable number of customers, large companies are also adapting to this situation and begin to advertise their efforts to substitute (what is considered) synthetic ingredients through natural ones. Such efforts are also getting much support from R&D projects (e.g. in regard to natural preservatives). Much knowledge from life-sciences and biotechnology is invested in analysis of better utilizing the products of nature than modifying them. SMEs and small companies are profiting much, because many of them are able to gain the trust of customers and co-operate with local organic farmers. Even large companies are co-operating with smaller ones in order to get more insight into natural and traditional recipes and for product sourcing.

Personalised diets and healthy eating are a very important aspect in this scenario, although the realisation is much more based on a trust in nature and the rediscovery of traditional solutions. Traditional Chinese and Indian diets and health recipes are being revitalised, scientifically assessed and even taken up by large manufacturers that are also beginning to sell traditional Chinese “Qi Food” and Indian Aryurveda-products based on traditional knowledge. Functional food may be based on the Indian concept of “sattvas” (harmony), “rajas” (energy) and “tamas” (negative elements that should be avoided). In Ayurvedic food theory, items such as fresh fruits, vegetables and milk are considered positive (sattva), rajvaic foods like coffee and “energy food” are considered somewhat risky and heavy foods like fat, meat, starches and alcohol are considered bad (tama), which somewhat reflects contemporary “Western” guidelines for healthy eating. Natural/organic food and fast food also do not have to contradict each other as examples of raw foods suggest.

GMO and food nanotechnology are nearly absent in Europe. Although some of it is principally allowed and has passed safety evaluation, the majority of customers neither wants nor needs it. On the other side, insects may be accepted as new food source for ethical and ecological reasons. Major innovations will be in the area of improved and more efficient and sustainable processing and new forms of natural preservation and refinement methods. The problem of fraud and “greenwashing” remains a problem that puts a great challenge on trust. However customers are quite well informed to uncover frauds and false advertisement and such revealing can ruin a company. The general trust in food and drinks is rather high, making it less pressing to develop high-tech testing methods.

Technological progress is viewed from different perspectives than rationality, high-tech, speed, machines and competition and the goals for innovation have generally become more focused on the environment, humans, society and the improvement of living quality. Also the attitudes towards economic goals have changed towards some extent and earning even more money is not the major goal of large parts of the society.

Possible innovations include:

- Regional and small producers
- Innovations in the utilisation of organic preservatives and ingredients
- Natural functional food
- Functional food based on Chinese, Indian or other (ancient) traditions
- "Ethical" food
- Fair trade
- Food-mileage becomes important
- More balanced vegetarian and vegan products
- Labels depicting the ecological footprint of the product
- Insect proteins
- Many service and process innovations (e.g. food advise)
- "Organic discounter".

Winners: SMEs, small local industries, organic producers, traditional firms, eco, fair trade

Losers: Large firms, companies that want to use GMO, nanotechnology, synthetic ingredients, conventional/"industrial" agriculture and production

Potential risks, barriers and challenges of this scenario:

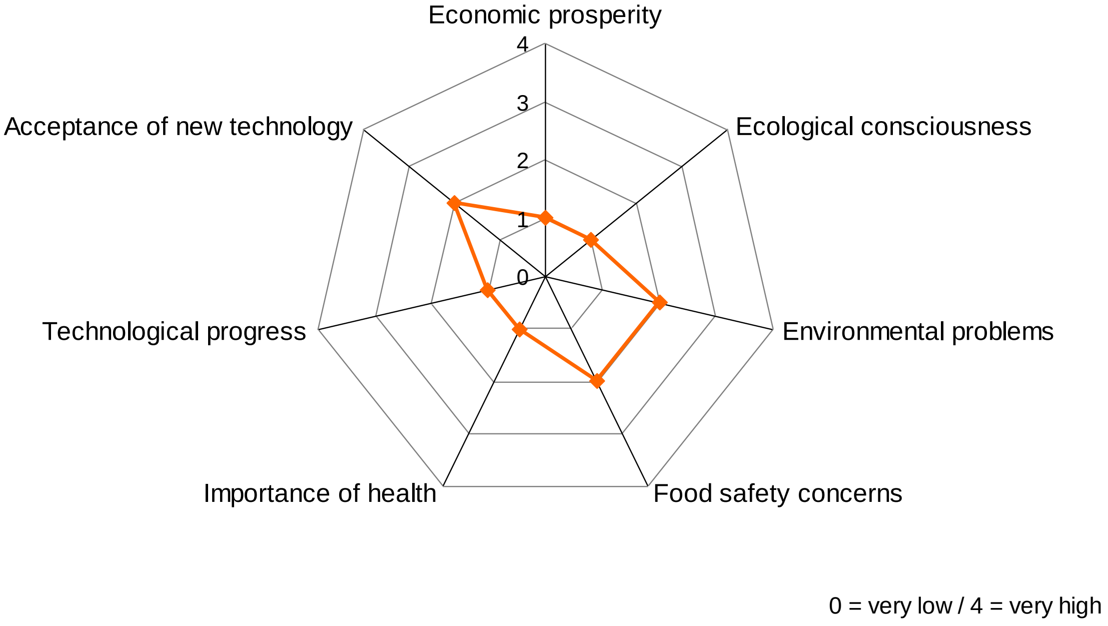
A decline in income, diminishing trust in the "organic" industry ("green washing") and declining interest in ecological and sustainability issues (e.g. because no real improvements are being perceived or people may not see enough evidence of environmental problems) may also negatively effect the current popularity of eco-oriented lifestyle and consumption patterns.

The scenario is only possible and sustainable for societies with comparatively small populations, a well organised agricultural infrastructure and sophisticated agricultural technologies. In many parts of Asia, for example, where the populations are large and even growing, organic farming could not yield enough output to ensure food security. If organic food production reaches a certain growth rate, this could also have adverse effects on land area, food prices, food security and obtaining a sufficient workforce in agriculture and thus be unfavourable for sustainability.

If Europe decides to opt for going further towards the direction of this scenario, importing food products from abroad, especially from Asia and the US could become problematic and food exports may become too expensive to be really profitable. Agricultural and food trade will thus mostly remain within countries that opt for similar trajectories. Extreme cases of this scenario also create a very fragile "monoculture" situation where disturbances and changes could even lead to challenges for food security and prices. Pressing problems, e.g. through climate change or other ecological occurrences which can also occur due to practices on the global scale, could even make GMO and currently disputed preservation methods into an acceptable option given the lack of viable alternatives (cf. scenario 5).

In general rather unlikely that thus scenario will be realised in it pure form, but a further shift towards this direction relative to the reference scenario could lead to improvements in health as well as ecological sustainability.

Figure 3.3 Scenario 3: Cheap & convenient



Driving factors and framework conditions: Within this scenario which is characterised by a rather unfavourable financial situation for advanced research and development, many of the scientific and technological possibilities cannot be practically realised because industries and institutes can not afford them. Due to decreasing capabilities in controls, quality standards are less good than they could be. Cheap production, rationalisation and automation are main drivers for innovation that is mostly focussed on process innovations and smart methods to further decrease production costs. The general trust in science and research is rather low.

The income situation of a substantial part of the consumers is not that good causing them to make affordable prices of products a major factor for their choice. Many people who were forced during the financial crisis to opt for cheaper products remain with this habit even after their financial situation improves. Additionally to this, consumers are getting increasingly confused about contradicting health advises and have become increasingly sceptical about the stated benefits of more expensive foods, “organic” products and health benefits of functional foods. People generally have less time (e.g. needing to take more than one job) and money (low paying jobs) and hence choose products that are cheap and convenient or indulging (or both), e.g. to counter stress. The food and drinks manufacturing industry as well as agricultural producers are also forced to lower prices, which leaves not much room for higher quality or innovative products. In the first place food should be affordable and taste sufficiently well. Since low cost is the major competition factors for retailers, a downward spiral towards low cost is being initiated that effects the whole food chain. For most consumers, inexpensiveness, convenience, and to a certain degree fun are most important. This also goes in parallel to a general social attitude of a present centred "living today", which puts less emphasis on future developments, long-term considerations and future plans.

Characteristics of the industry and products: Health foods and organic products are loosing ground with mass consumers and are rather considered as high-end products for the economic elites. Also the interest in science-based nutritional recommendations is fading due to contradictions (like the contradicting findings over Ginkgo, resveratrol, calorie restriction, vegan diets etc.) and lacking trust. The increase in labels on products had the opposite effect as intended: people lost interest in reading all the information and rather buy on basis of past experience, emotional reactions and especially price.

The general wealth of elderly people is also lower than expected, so that many cannot afford the much more expensive science-based health foods and drinks, thus leading to less interest in their development and the issue of healthy aging in general.

For large food and drinks companies and warehousing robotics gets increasingly important since it enables cheaper production. Also conventional and industrial farming will remain the norm and drives further innovations, also in regard to "feeding a growing world population". Food is being imported from where it can be grown and manufactured in cheaper ways, which also becomes easier since the precaution-based concern over safety and ingredients is fading and controls can not be held up sufficiently.

Possible innovations include:

- Advances in food processing automation, logistics and warehousing
- Variety of fast and convenience food (with some healthier and less healthier varieties)
- "Fashionable" foods and drinks – goods, often associated with "youth culture" and franchise
- Indulging foods where taste and experience and not necessarily health are in the main focus
- Snacks, microwavable products etc.
- Alcoholic drinks, energy drinks at reduced prices
- Value chain integration

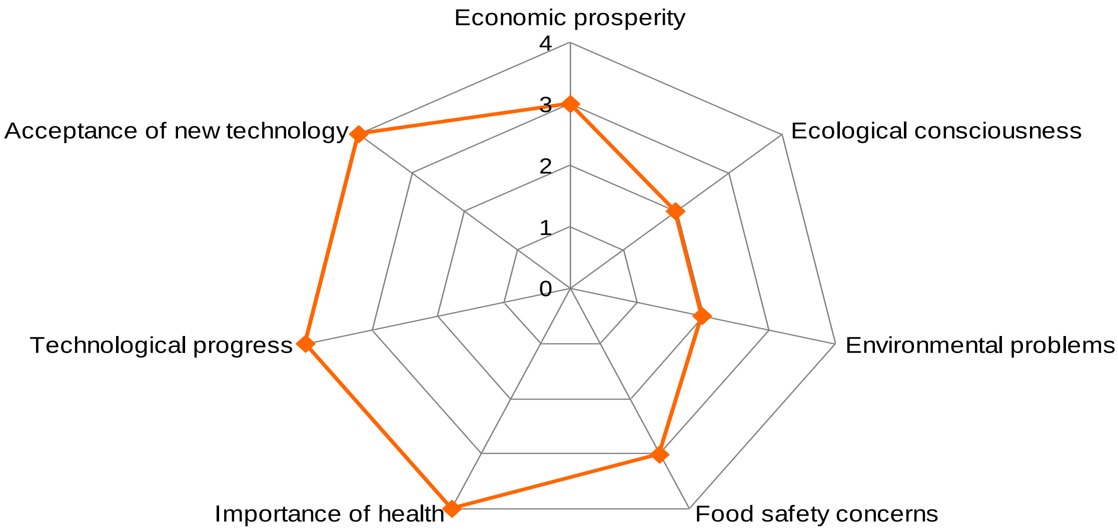
Winners: Large companies, cheap manufacturers and retailers, private labels, fast food, convenience food, "industrial" agriculture and processing, automation

Losers: Expensive producers, organic foods, luxury foods, expensive health food, scientific approaches

Potential risks, barriers and challenges:

Highly industrialised and rationalised farming and food (and drinks) production are especially criticised in regard to environmental and health problems (e.g. obesity related illnesses). Although highly industrialised food production could enable better food safety controls, the objective of price reduction could lead to declining quality and lacking resources for innovation, research and development. This scenario also goes together with other factors like a rather bad economic situation and a general declining interest in the future, innovations and long-term considerations, which also negatively affects the concern over sustainability. Generally this scenario leads to a downward spiral in sustainability as well as quality and a further shift of this scenario relative to the status quo would quite likely lead no negative implications for health, wellbeing and the environment. This scenario could become more likely if the driving forces behind the “Going Natural” scenario decline and if the economic situation and public attitude towards health, innovation and longer-term goals also fade away.

Figure 3.4 Scenario 4: High-tech nutrition



0 = very low / 5 = very high

Driving factors and framework conditions: The advances in bio(techno)logy, ICT, nanotechnology and other related scientific areas as well as the interest of the public and policy makers is growing fast and there are many spill-over effects to the food and drinks industry. In this scenario, scientific research has shown that some forms of GMOs, certain types of nanotechnology-based ingredients and medicinal functional food are sufficiently safe and show no adverse side effects. A substantial part of the population has high trust in science and research and therefore also trusts these findings and derived products. What has started within circles of technological experimenters (and prominent figures, e.g. from sports and business) that have tried out food and drinks innovations in the areas of functional and medicinal foods to improve health, prevent diseases and improve fitness and wellbeing, is soon being followed by the masses. The general economic situation is rather good and people are willing to invest much into their health.

Customers are becoming increasingly interested in quick and technology-based solutions for improving their health as well as physical and mental potentials. Governments as well as health insurers discover the cost-effective value of functional nutrition and even medicinal food for public health. These expectations have also been the driving force behind governmental support for functional food research and advertisement through medical professionals, nutritionists and health insurers. The market expands rapidly as scientific and technological insights grow. Although some technology applications are still rejected by some consumers, their perception gets more differentiated. Consumer decisions are generally very much based on what science and research are saying, a fact that is also being capitalised by advertisement.

Characteristics of the industry and products: New discoveries in genetics, epigenetics and nutrigenomics as well as medicine and other areas of life science are constantly leading to new innovations in food and drinks products and improvements, whereas the dimension of science and technology plays the major role. Even products that may taste not that good are being bought if some research states that the benefits for health and fitness are high.

Some examples are improved bioavailability of ingredients based on nutritional science analysing the interaction of different nutrients as well as methods borrowed from medicine like drug targeting, personalised diets, smart labels, science-based functional foods and the development of so-called “mood food”, “brain food” and “fitness food” that positively influences wellbeing, physical properties and cognition.

Computer technology is also of great help, e.g. in regard to food development, nutritional calculation and simulation and the development of personal diets (e.g. genetic analysis).

Researchers and customers have also discovered the important role that food can play in the prevention of diseases. Therefore according developments are supported by governments and health insurers in the context of public health improvement.

Although GMO and nanotechnology etc. is still rejected in some areas where the scientific concerns over profound health risks exist, it is supported in others, e.g. for the creation of allergen-free products, the creation of more nutrition-enriched crops and plants, for increasing (not decreasing) the number of different crop varieties or reconstructing older crop species, as a method for faster “cross breeding” and for designing animals with improved immunity thus necessitating less antibiotics. Also cultured meat is gaining popularity and products are improving fast due to increasing demand and support, also from animal-rights groups and environmentalists.

Especially large companies have an advantage in this scenario since they have the best financial and scientific means to achieve the goals. But also smaller companies play an important role because they often focus on specific issues and challenges and occupy profitable niches or are able to serve as specialists within consortia and collaborations.

Although traditional food and recipes still exist, they are also being improved in regard to health aspects and the traditional producers need to keep up with “upgrading” their products. Many SMEs get governmental funds to help them improve traditional foods while still preserving the cultural heritage. Traditional foods and drinks that are e.g. based on ancient Chinese traditions are also being assessed in regard to their scientific credibility. The products that are science-based are being accepted whereas others are soon disregarded as fraud and nonsense.

In general this scenario is the most technologically sophisticated and most expensive one and requires considerable investments in R&D and innovation activities as well as support from the public and policy-making (e.g. in regard to laws and regulations). Since the general importance of the food and drinks manufacturing sector has grown rapidly, more and more students are getting interested in the subject and the industries are able to easily find appropriate personnel.

Possible innovations based on chapter 3.1:

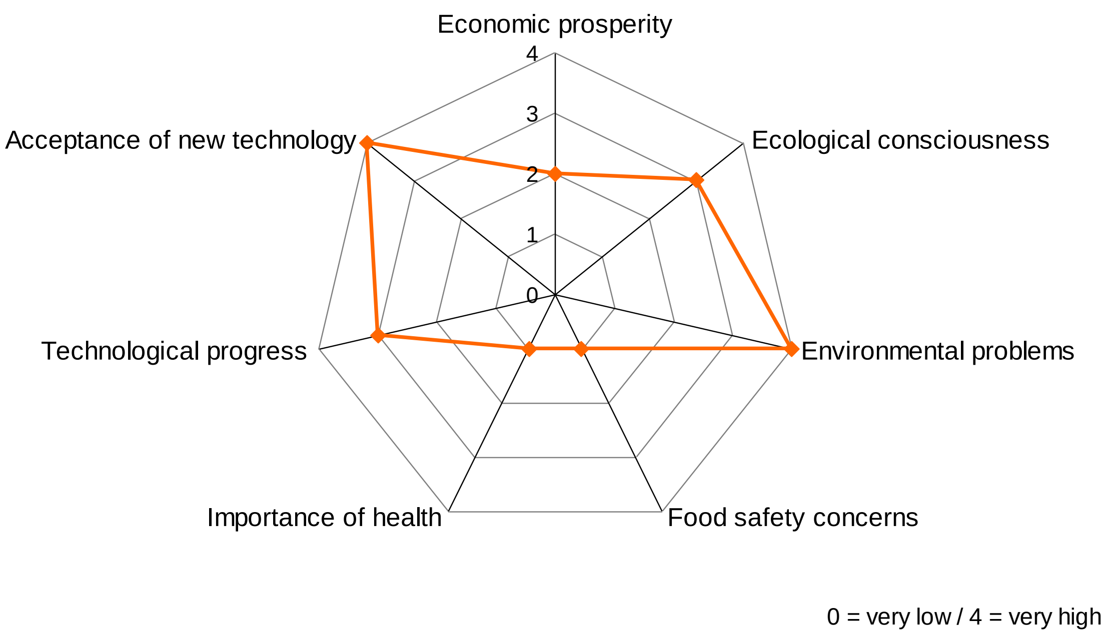
- Science-based functional food (e.g. on basis of nutrigenomics)
- Selected applications of GMO for innovative products like allergen-free nuts (“knock-out nuts”)
- Non-prescription nutraceuticals and medicinal food
- Cultured animal protein
- Functional food (mood, cognition, beauty/cosmetic)
- Healthy convenience food
- Improved traditional foods
- Service innovations like science-based recommendations for optimal food combinations
- Combinations of traditional knowledge (e.g. Ayurveda) and high-tech (e.g. nano encapsulation of nutrients to improve bio-availability)
- Adjustable food, e.g. the possibility to regulate spiciness or other taste characteristics according to microwave settings

Winners: Large companies, innovative start-ups (especially in close relation to biotech, nanotech, ICT), scientists, interdisciplinary R&D, functional food companies

Losers: Non-innovative SMEs, traditional firms, unhealthy fast food.

Potential risks, barriers and challenges: Many of the innovations being mentioned are costly in their development and need many human and financial resources. Some of them are also dependent on general scientific discoveries, e.g. in genetic and molecular research. So a lack of human resources or scientific means and backing could make the realisation of this scenario difficult. Above this, some consumers may generally object to some of the mentioned methods and technologies. This scenario also rests very highly on technological solutions and thus also represents a “monoculture” that bears dangers if either some assumptions (e.g. about safety) are wrong, the products do not yield the expected results as assumed (e.g. with functional and medicinal food) and food security could be endangered if financial and human resources may decline. Humans may also become alienated from real food and real agriculture. This could make an overemphasis on technological solutions dangerous in times of crisis and decline. Especially small traditional manufacturers are threatened in this scenario and the dependency on R&D and other sectors and developments is very high. Judging from current trends, a pure version of this scenario is also quite unlikely, but a further shift towards this scenario could also improve the overall quality of food and drinks products and certainly stimulate innovation. If balanced by the “Going Natural” scenario both could improve each other through complements if they do not remain too opposing.

Figure 3.5 Scenario 5: Emergency



Driving factors and framework conditions: The “Emergency” scenario will depict a very grave situation, where innovation is not merely a means for staying competitive, but for staying alive. Climate change and environmental destruction will lead to drastic decreases in arable land while the global population is still rising with many environmental refugees coming to Europe. Many countries, even in Europe, will face systemic food shortages, e.g. due to lacking arable land and crop failures, e.g. due to extreme weather conditions and the results of overfishing and animal diseases. The only way out of the crisis lies in innovations that drastically increases yields and arable areas or create crops that can grow under harsh conditions (extreme draught, extreme rainfalls), find new protein sources and improve food preservation.

The general economic situation is not good, but due to the importance of the issue, significant amounts are being invested into nutrition-related research and development. New technologies are accepted quickly if they show promises to solve rather immediate problems.

The situation in many non-European developing countries is even far worse, leading to socio-political tensions and environmental refugees to Europe. In this sense, Europe also assumes and obligation to find quick solutions for de-escalating the problem.

Characteristics of the industry and products: Under these conditions, a variety of alternatives are being tried out and all are welcome and get implemented quickly. Such innovations may include genetically modified crops and fungi to resist harsh conditions, improve yields or diversity (i.e. to have some 'backup' crops if external conditions change or some plague will hit), genetically modified animals optimised for food consumption, indoor farming and lab-grown meat as well as the utilisation of (perhaps also genetically modified) insects as fast-reproducing food source. The roofs of buildings are being transformed into agricultural spaces and gardens are mostly serving food production than planting flowers. New food preservation methods are being thought of to maximise the reserves. Research and technologies that have initially been developed within the context of the space programmes are now re-initiated and deployed on earth. Major examples include technologies for water filtering and recycling (e.g. rainwater and even urine), large scale algae production, farming in large 'terrariums' like Biosphere 2 and greenhouses designed for the Mars mission as well as food pills and 'field rations'.

Possible innovations include:

- GMO food to be grown under extreme environmental conditions
- GMO to enhance crop yields and the utilisation of animal proteins
- Indoor farming, alternative farming methods
- Alternative protein sources (e.g. insects)
- Development of new food sources
- Improving the efficiency of food usage, reducing food waste
- Food pills
- Optimised nutritional intake (e.g. nano-encapsulation)

Winners: All those that come with working ideas to produce and preserve food

Losers: All those who do not come up with suitable ideas

Potential risks, barriers and challenges: Besides everybody hoping that this scenario will not become reality, it nonetheless shows that a general lack on innovative ideas (regardless of current acceptance) could pose grave problems under certain conditions. This scenario also shows that some of today's rejections about certain technologies and ideas are embedded within current socio-economic conditions that do not require drastic measures. If external conditions change, GMO, disputed food preservation techniques (e.g. irradiation), entomophagy (insect eating) and food pills may become acceptable given the alternative of insufficient food and water. However this scenario certainly leads to general declines in health and wellbeing and is, in contrast to the "High Tech Nutrition Scenario", seen as a last resort rather than a choice. The scenario also shows possible developments that can occur due to lacking concerns over the environment and sustainability and could even represent and extreme result coming out of the "Affordable & Convenient" scenario. It depicts a situation where everything goes wrong and is getting out of balance, but it also depicts the reality in some countries stricken by environmental catastrophes, draughts and poverty, which not even have the sufficient means to apply undesired technologies as last resort.

Scenarios: concluding remarks

If deriving from the assumption that affordable improvements in health, safety and sustainability are the main goals of innovation activities, then the scenarios “cheap and convenient” as well as “emergency” are definitely not favourable. Nonetheless “cheap and convenient” may become a growing trend for low income groups and people who lack sufficient knowledge about nutrition or time for adequate food preparation. Especially obesity is a major health concern that is also associated to “junk food” and unhealthy eating and lifestyle habits. Also many food safety and quality problems are attributed to the drive for more cost reductions and thus cost efficiency and quality are currently in a way antagonistic. Therefore innovations should also keep the cost factor in mind and look for solutions that improve quality in an affordable way. If new technologies for healthier ingredients, improved preservation methods and faster and real-time safety assessments are getting cheaper, improvements could also reach the lower budget sector.

The “emergency” scenario is certainly a kind of worst case scenario where even food security (enough food) is in jeopardy, but if sustainability will be neglected, this could become a realistic outcome. Current trends in desertification and reliance on monocultures in large scale agriculture already seem to point towards this direction and in many countries around the world the situation for food security and safe drinking water is already bad and still worsening. The “business as usual” scenario is not a very innovative one, but since it is very diverse and different factors like factory farming on the one side and ethical and sustainable food production on the other keep each other in balance in regard to cost reductions, sustainability and health. Nonetheless, this scenario could lead to an even greater gap in regard to nutrition-related health in the future with expensive health and natural food on the one side and cheap and unhealthy “junk food” on the other. Also innovativeness may become quite selective, dividing the industry into highly innovative sections and non-innovative less healthy low budget areas.

On first glance the “going natural” and “high-tech nutrition” scenarios look like contradictions which may even be the case if taking their extreme forms. But both can also be combined by leaving out developments that are considered risky or insufficiently assessed and focusing on the deployment of new technologies (as they are also being mentioned in the section about innovation themes) to improve health, sustainability as well as affordability. Some of these cross-cutting innovation areas may be:

- Assessment of functional (natural) ingredients as replacements for less healthier ones
- Personalised diets
- Evidence-based functional food
- Reduction in fat, salt, sugar and other problematic ingredients
- Alternative proteins
- Improved preservation methods
- Advanced and continuous food testing
- Sustainable production (energy efficiency, waste and water reduction)
- Automation in processing (could improve hygiene)

3.4 Future innovation themes and corresponding linkages with other sectors

As products become more advanced and complex, insights from other thematic and research areas can greatly contribute to innovativeness. Interdisciplinarity is becoming increasingly important for the food and drinks manufacturing industry as the interlinkages with, for example, food, modern biotechnology and ICT-related technologies show.

The food and drinks manufacturing industry has close linkages with both upstream and downstream sectors, ranging from, inter alia, primary agriculture, logistics to packaging, branding and store management. It has numerous interdependencies and interlinkages with different research areas, including rather obvious ones like biology and biotechnology, genetic science, health and medicine, chemistry and physics and material science. Both also human-oriented behavioural sciences like social, cultural and even religious studies, psychology, economics and marketing play an important role. In recent times, age-related science (gerontology), environmental sciences and legal studies have grown in relevancy for the food and drinks industry.

RFID tracking, lab-on-a-chip systems for food testing, nanotechnology for smart food packaging that automatically detects spoilage and smart materials for improving freshness, genetic science for a better understanding of the impact of nutrition on gene expression as well as neuroscience for the development of innovative functional food and automation and robotics are all important developments for improving the performance of food and drinks manufacturing sector.

Inputs from biotechnology and life sciences

Bio- and life-sciences will substantially shape the future food and drinks industry and their products. One emerging area of science which could profoundly influence food and drinks products is epigenomics (epigenetics). In contrast – or as addition – to “classical” genetics, epigenomics is concerned with the changes of gene expression and the regulation of gene activity that are influenced by external factors like food intake or exposure to substances found in the environment. In short, new scientific findings strongly suggest that there exist a so-called epigenome that controls in how far specific genes are “switched on or off”, i.e. being active or inactive (through influencing DNA or protein methylation). Influences affecting the epigenome may even be inherited to offspring. Since the intake of food and drinks is regarded as an important influencing factor for the epigenome and thus affecting genetic expression and determining certain characteristics in the organism, e.g. their health state, it is very likely that the food and drinks of the future will take these findings into account. These findings may also put new responsibilities onto the food and drinks industry and agriculture.

There already exists a specialised research field based on epigenomic theory, called nutrigenomics. The European Nutrigenomics Organisation (NuGo), for example is a Network of Excellence in the EU Sixth Framework Programme for Research and Technology. The main goal of this organisation which has 23 partner organisations within 10 European countries is the improvement of the European nutrigenomics research. (NuGo, 2009). It studies the relationship between nutrition and the genome, epigenome, metabolome (molecules involved in metabolism) and proteomics (expressed proteins). Related research has also shown that individual persons can possess a different enzymatic makeup (polymorphism) that makes their metabolism work differently, leading to differences in the utilisation of nutrients (and medication). This could lead to new services offering personalised recommendations for food and drinks intake and combinations.

Already today, some biotech firms are offering personalised nutritional consultation on the basis of genetic analysis, but science is currently still not able to understand all the complex underlying mechanisms to provide meaningful and evidence-based advice. However, scientists around the world are researching in this area, trying to uncover the complex interlinkages. Progress in computer technology is of great assistance for enabling the necessary complex calculations. Also the enormous progress that has been made in DNA analysis – in regard to speed and cost reduction - is also a contributing factor that genetic and epigenetic findings might be integrated into tomorrow’s food and drinks.

Out of these developments, the following trajectories are likely to evolve within the next 15 to 20 years:

- New and improved functional foods and drinks, in combination with possibilities of personalised diets (at least to a certain degree) will be a likely development within the next 15-20 years. Especially natural functional ingredients will get increasing positive attention through consumers, the industry and research. New categories like foods and drinks with mood and memory-enhancing effects could also be developed and may attract a large share of customers. The regulatory framework in this regard is uncertain at present. If there will be drafted a regulatory framework on so-called “Human Enhancement Technologies” as it is currently being discussed at STOA (FIH, 2009), foods and drinks on the blurry line between foods, medicine and “drugs” will certainly become an issue.
- Medicinal food and GMOs for pharmaceutical purposes (although it might become technically feasible within this time frame, it will encounter much more regulatory hurdles and costs.)
- Cultured meat, i.e. meat produced from cell cultivation in the laboratory without the need of growing and slaughtering a whole animal, could also become feasible for industrial-scale use to a certain degree within the next 20 years. The progress is likely to be faster if sufficient financial support and research-co-operation are being provided.
- Food testing methods and food chain management will certainly improve very much due to new technological possibilities like instant testing, improved lab-on-a-chip systems, smart sensors and smart labelling, improved preservation methods and a better scientific understanding about the reasons for food contamination, spoilage and the behaviour of harmful micro-organisms. Molecular biotechnology and nanotechnology are also likely to be welcome in the area of food testing and surveillance, perhaps in contrast to their usage in the food and drinks themselves.
- The principal possibilities for food nanotechnology are likely to grow within the next 20 years; the trajectories will depend much on further safety evaluations and consumer acceptance.

Functional foods

Whereas today's functional food relies on (assumed) knowledge about specific ingredients that could yield specific effects in humans (e.g. better digestion, lowering cholesterol, binding of free radicals, improve wakefulness), future functional foods could be designed on the basis on findings from epigenetics and epigenomics as well as medical research, i.e. being evidence-based. If it will be known how specific ingredients in foods and drinks influence DNA methylation (determining which genes become active and inactive), leading to certain positive or negative effects (e.g. affecting the probability of cancer, overweight, life expectancy), future food might be engineered in a way to purposefully remove or insert certain substances. Also the bioavailability of nutrients could be improved if our understanding about metabolic and proteomic mechanisms will grow. The design of future functional food may go beyond the supply of nutrients as such and will be based on a holistic molecular approach to nutrition.

1) Functional food for the brain and nervous system: Research suggests that there is a connection between specific nutrients and mood, memory, cognition and the nervous system. Neuroscientists and neurobiologists are currently analysing these complex mechanisms between brain chemistry and nutrition. The findings may lead to science/evidence-based nutrition that specifically affects mood, cognition or other neural functions, e.g. by adjusting the serotonin-level in the brain as well as that of other neurotransmitters. (Serotonin is a neurotransmitter responsible for regulating mood, aggression and appetite and can be responsible for depressions. The production level of serotonin can be influenced by foods, e.g. raised by carbon hydrates).

2) "Anti-ageing" food/drinks and products for the elderly: Customised diets for the elderly are getting increased interest in the context of rising life-expectancy. Weight loss and malnutrition are quite common in elderly and can also be attributed to changes in biological and biochemical bodily processes due to ageing. Nutrition for the elderly also stands in the intersection of geriatrics (study of the diseases commonly found in elderly), gerontology (the interdisciplinary study of aging) and the emerging field of bio (medical) gerontology (investigating the biological process and causes of aging) together with scientific disciplines dedicated to genetics and nutrition. But nutrition for the elderly is not only a medical problem. Elderly people are often less sensitive to taste and smell and might have problems with moving or chewing, thus negatively influencing their eating habits, perhaps necessitating other forms of innovations that can compensate for these circumstances (cf. Fillion/Kilcast, 2001).

Future food and drinks could be engineered to counter certain negative age-related effects and thus having preventative function and supporting quality of life and healthy aging. Ways to counter and prevent age-related diseases are currently very high on the research agenda in food research, biotechnology and medicine.

Personalised diets

As mentioned above, humans have different metabolisms; hence a certain nutrient can have different effects in different persons. With science progressing, it may be possible in the future to compose individualised diet plans based on genetic information and epigenetic findings, optimised for the individual person's biological makeup. This could be performed in form of composing personalised functional foods or in just making recommendations for food choices (e.g. for some individuals it may be better to eat more meat, whereas for others a vegetarian diet might be preferable). The continuing trend towards cheaper and faster genome analysis is an important factor for the realisation of personalised genetically-based nutrition (al) advises.

The customer interest in the concept of personalised nutrition is already quite high, although the topic is still a scientifically emerging issue, and far from usable industrial results yet. The customer interest may also be the result from the general current trend towards customisation and individuality, independent from the issue of nutrition. Researchers and public health specialists are also very interested in these new areas of research, because of the prospective of providing new and rather easy ways for disease prevention (especially in regard to so-called life-style diseases, but also concerning cancer or dementia).

Currently, research in the fields of epigenetics, nutrigenomics, proteomics, metabolomics and related areas is well supported and advances in analysis methods and computer technology provide positive contributions. A general trend towards a nutrition approach based on these new research areas is very likely to be realised. However, the ability to understand the complexity of genetic information and developing specific plans in regard to individualised nutritional advises is currently still very much in its infancy. Further developments and applications will depend on scientific findings and theories that still need to be made or better evaluated.

Medicinal food

In ancient traditional China and India, as well as in other cultures, food and medicine have been closely related, with specific foods used in therapeutic applications and functions. This ancient idea has been taken up by modern biotechnology and medicine. One direction in which this research has developed is the creation of foods that can have the same effect as vaccinations, e.g. against polio, measles or diphtheria. The positive side of it would be that one could actually use nature's own methods to produce specific medicinal substances and that the "vaccination" could occur just through eating. In principal – although not yet in (approved) practice -, genetic engineering technology can be used to create plants (e.g. banana) that contain the specific vaccines. However, these suggestions have come under some criticism concerning their effect and safety (and the safety of genetically modified organisms (GMOs) in general) as well as legal problems (different regulations apply for food and medicine) and the scientific and technological progress has been limited so far. For this reason, related research is slowing down. A similar method, called (molecular or gene) pharming, however is experiencing growing applications. In pharming, genetically modified plants and animals are used to produce specific medicinal active components for applications in the pharmaceutical industry or other biological components that are utilised for industrial purposes, including food ingredients. Future GMOs for pharmaceutical use. Although it would be technically possible to create genetically engineered plants that produce pharmaceutically usable components, current political, legal and ethical problems as well as unclear safety issues can be named as hindering factors. Principally this currently still applies to all GMOs in food and agriculture.

Cultured meat

As scientific and advances are being made in stem-cell technology, cloning and tissue engineering, researchers have asked the question why not growing meat in the laboratory using the same techniques. Instead of breeding and raising chicken, for example, in order to slaughter them to get their meat for food, not the whole chicken, but only the meat (the meat cells) might be grown in the laboratory. The requirements for cultured meat are even below those of medical tissue engineering which has to be functional for therapeutic purposes.

The environmental group PETA has offered a 1 million USD prize to the contestant who successfully produces and sells the first cultured (in-vitro or lab-grown) chicken meat until 2012 (Mongabay, 2008). The Dutch researcher Henk Haagsman from University Utrecht is leading a research project about cultured meat in co-operation with scientists from University Amsterdam, Utrecht University and Eindhoven University of Technology, partially funded by the Dutch government. Also the non-profit research organisation “New Harvest” is working on the development of meat substitutes.

In general, it can be assumed that scientific and technological advances in tissue engineering will make the development of cultured meat easier in the coming time, especially since it is much easier to create tissue for food than for medical purposes (e.g. organ transplants in humans). Here biomedical science and food science can profit from each other in a rather unconventional way. However, the factors of quantity and time (to produce large amounts of sufficiently textured cultured meat in a short time) as well as the provision of nutrients to the tissue still remain a challenge.

Insects

Insects (and a variety of worms) are actually a very efficient food source and display a better nutritional and ecological efficiency than other animals that are commonly consumed in European countries (especially pork and beef). The issue of making more use of insect sources for nutrition has also been evaluated at a FAO conference in Chiang Mai, Thailand in 2008. Around 1400 insect species are already being consumed, especially in countries on the Southern hemisphere and new processing methods could actually make their use more attractive, even to Westerners. Also new standards and testing have to be established if broader insect consumption would be established to avoid harms from insecticide residues (FAO, 2008). Since insects are nutritious, available in large amounts, reproduce fast, necessitate little space for keeping and can be produced cheaply, they could become economically and ecologically relevant. Entomophagy (insect eating) is already quite widespread in South Asia, Africa, Latin America and Japan, but not in Europe and North America.

Fast food and convenience food

As is seems that some people are having less and less time for cooking and lengthy food preparation, innovations in fast and convenience foods are also being thought of. One major issue is the production of healthier fast food, e.g. by reducing trans-fats, sugar, salt and preservatives that are considered unhealthy. The other issue is increasing convenience, e.g. making preparation even faster or even mobile, e.g. by using self-heating or self-chilling (e.g. for drinks) packaging. However, concepts for self-heating and cooling have already existed for quite a while, but never became really popular so far. However, fast food is currently often also associated with low budget and unhealthy choices, but both aspects could be changed. Healthy and higher quality (and higher priced) fast and convenience food are well conceivable and could especially address working professionals. Fast food producers can also serve as trendsetters to respond quickly to legal requirements (e.g. in regard to ingredients and trans- fats) or customer wishes (e.g. ecological sustainability or fair trade), whereas it can not always assessed if some measures are only superficial or real innovations. Fast food producers may also need to adapt to customer's wishes and changes in trends in an early manner and thus could also serve as early indicator for other branches in food and drinks production.

Challenges and barriers:

Cost pressure may be named as one of the major barriers for quality-related innovations in fast and convenience food, but as mentioned above, fast food and low budget do not necessarily have to be related. As customer concerns over healthy nutrition, environmental considerations as well as fair trade and animal rights rise, fast and convenience food producers may get increasingly criticised over some of their practices and some measures like their advertisement with healthy choices or environmental consciousness may not be really believed by the customer. However as also mentioned above, regulations and legal pressure could especially lead to innovations and changes in the fast and convenience food industry due their already fragile image.

Functional natural ingredients

Research advances in biosciences not only lead to trajectories of greater modification but also provide better insights into the mechanisms of natural ingredients that can possess valuable properties for preservation (e.g. wasabi, rosemary) or other beneficial functional properties (e.g. for health but also for enhancing properties during processing). Although natural ingredients have already been utilised for quite a while in Western as well as Eastern diets, scientific analysis can help to assess their workings in an evidence-based way and enable more specific utilisation. Also advanced microencapsulation techniques that represent an emerging method for improving food processing and nutritional value of food can be based on natural materials such as starch, proteins or lipids.

Nano-based food and drinks ingredients

Nanotechnology (in combination with methods from biotechnology) is not only considered for packaging, but also as food ingredient. Despite consumer concerns, nanotechnology has already reached the supermarket shelves, e.g. for improving the texture and viscosity of products like tomato ketchup and chocolate. Nanotechnology (i.e. nanoparticles and nano-capsules) are currently being evaluated for use in targeted drug delivery, e.g. for methods to enable the release of medication only in the area where it is needed. Similar techniques could also be applied in the food and drinks industry for improving the release of nutrients, vitamins or flavour and for enhancing their bio availability. In general, nano-encapsulation, nano-emulsions and similar nano-based techniques seem to show advantages over "classical" non-nano methods in regard to controlled delivery, better food-matrix integration and avoiding undesired tastes.

Another thinkable, but more far away innovation could be the creation of "customer taste adjustable foods" or "programmable foods". Flavours or colours could be contained in nano-capsules that release their content only upon a certain temperature, microwave setting or other triggering effects. The customer could therefore choose the flavour or colour through different heating times or microwave-oven settings. Although such innovations are within technological possibilities, it is currently quite questionable if they will be accepted by the customer. (cf. EC, 2006; WDR, 2008; Nanowerk, 2009).

Table 3.1 Examples of food/drinks nanotechnology:

Agriculture	Food Processing	Food Packaging	Supplements
• Single molecule detection to determine enzyme/ substrate interactions • Nanocapsules for delivery of pesticides, fertilizers and other agrichemicals more efficiently • Delivery of growth hormones in a controlled fashion • Nanosensors for monitoring soil conditions and crop growth • Nanochips for identity preservation and tracking • Nanosensors for detection of animal and plant pathogens • Nanocapsules to deliver vaccines • Nanoparticles to deliver DNA to plants (targeted genetic engineering)	• Nanocapsules to improve bioavailability of neutraceuticals in standard ingredients such as cooking oils • Nanoencapsulated flavor enhancers • Nanotubes and nanoparticles as gelation and viscosifying agents • Nanocapsule infusion of plant based steroids to replace a meat's cholesterol • Nanoparticles to selectively bind and remove chemicals or pathogens from food • Nanoemulsions and –particles for better availability and dispersion of nutrients	• Antibodies attached to fluorescent nanoparticles to detect chemicals or foodborne pathogens • Biodegradable nanosensors for temperature, moisture and time monitoring • Nanoclays and nanofilms as barrier materials to prevent spoilage and prevent oxygen absorption • Electrochemical nano-sensors to detect ethylene • Antimicrobial and antifungal surface coatings with nanoparticles (silver, magnesium, zinc) • Lighter, stronger and more heat-resistant films with silicate nanoparticles • Modified permeation behavior of foils	• Nanosize powders to increase absorption of nutrients • Cellulose nanocrystal composites as drug carrier • Nanoencapsulation of neutraceuticals for better absorption, better stability or targeted delivery • Nanocochleates (coiled nanoparticles) to deliver nutrients more efficiently to cells without affecting color or taste of food • Vitamin sprays dispersing active molecules into nanodroplets for better absorption

Source: nanowerk.com, 2009

Smart food packaging with nanotechnology

The combination of nano- and biotechnology may also open up new ways for improved food safety control and surveillance. Nanotechnology enables the creation of ultra-small thermo-sensors that can cause colour changes depending on temperature. This allows for visual indications of broken cooling-chains, for example. Such labels are already being marketed but still rather expensive. In the future it is expected that the technology will get cheaper and with this more wide-spread. Future sensor technology will be able to react towards a broader variety of substances and smaller amount in real-time with improved accuracy.

Nanotechnology in packaging is also used for the development of packaging films that absorb UV radiation for better protection of light sensitive food ingredients. Other research areas are protective films that have anti-bacterial/anti-microbial properties ("active packaging") or block moisture, oxygen and other gases and substances from reaching the food and drinks, or to create packaging that is more heat or cold resistant. But also inspirations from medicine might someday enter food packaging.

Targeted drug release technology, which makes use of specifically engineered polymers that release medication over time at a controlled rate, are under development. Applied to food or food packaging, a similar technology could be used to release preservatives, flavours or other substance on an interval level (cf. AZo Nanotechnology, 2009).

Food preservation methods

New preservation methods for foods and drinks are not only about preventing spoilage, but aim at maintaining as many vitamins and nutrients intact as well as achieving better results at keeping taste and texture.

Since heating (and freezing) tends to destroy vitamins and nutrients or has negative effects on taste and texture, non-thermal preservation methods are getting increasingly attractive. Many new methods are currently being tried out or under development, and some of them are likely to be cost efficient enough to be used commercially in the near future. Because most food and drinks are generally products prone to spoilage, innovations in preservation are very important to the food industry by minimizing the necessity to throw away products which leads to losses for the industry and retailers.

Antimicrobial systems for food preservation

The use of ionized radiation for destroying microorganisms in food and drinks products is a common method, but not accepted by some consumers because it utilised radioactive radiation, although the food does not become radioactive through this method. Some consumer organisations also express concerns that irradiated foods lack vitamins.

Protective bacterial culture can also provide anti-microbial functions, prevent spoilage and the production of toxins and thus serve as substitutes to chemical or heat preservation. Finding suitable bacterial cultures necessitates research in molecular biology and interdisciplinary co-operation (cf. ETHZ, 2007).

Current research is also aiming at identifying natural antimicrobials like wasabi or rosemary and figuring which types are most suitable for which kind of food and drinks. The further progress in this area will depend on new insights and research in molecular biology / micro-biology and the interaction between different components. Here effectiveness and toxicity of potential antimicrobial agents have to be evaluated. Genetic engineering could also be used to create specific antimicrobial systems.

High pressure conservation (pascalisation)

If food products are exposed to high pressure (500 – 10000 bars) over a period of several minutes to hours, the same reaction effects can occur that would also happen under great heat. This leads to a kind of “heatless cooking effect” in regard to texture and more importantly, micro-organisms will be destroyed without negatively effecting important nutrients, aroma and colour. Since the proteins being changed through such pascalisation have better properties than those being exposed to heat, high pressure conservation could also lead to improved meat, fish and milk products. High pressure, together with supercritical carbon dioxide is also applied for extraction (e.g. of oils, lipids etc.) instead of using solvents like alcohol or hexane, yielding more gentle and environmentally friendly results. Currently the pascalisation still necessitates new equipment and high investment costs. Currently the technology is mostly used for high-end products.

Pulsed electric fields

The use of pulsed electric and magnetic fields (and ultra sound) is a novel form of food preservation which is already used on the industrial scale. The method destroys harmful micro-organisms and promises long shelf-life preservation by maintaining a very good quality in flavour, nutritional value and freshness. With this method, micro-organisms are killed by breaking their cell membranes when the food is placed within a high electric field induced by a high voltage. It is especially suitable for liquid foods like juices, milk products, soups and liquid eggs (cf. Ohio State University, 2005).

Converging technologies for food safety testing

Currently, it takes rather long until dangerous bacteria can be discovered in the food chain. Samples of the products have to be taken and sent to a lab for analysis, which could take days in the worst case. MEMS-technology (micro-electromechanical systems) has made it possible to put sensors, optical components, so-called fluid channels and microscopic pumps on a microchip-like device to run complex laboratory tests. These small devices have the advantage to be mobile and run analysis in much shorter time. Improvements in micro- and even nano-scaled sensor technology and the system-integration of nano-bio-sensors (containing biological elements that serve as sensors and physicochemical components that transform the detected bio-signature into a machine/human readable form) is making LOCs increasingly attractive for the food industry. This technology enables fast and on-the-spot analysis for the detection of various contaminations (cf. Sozer/Kokini, 2008). LOCs are already being used in medicine (e.g. for detecting cancers, bacteria, blood analysis), public health (e.g. disease control) and water testing. They are generally getting more versatile (detecting an increasing variety of substances) and precise. Further price reductions may in the more far away future even lead to throwaway sensor systems that could be integrated into food packaging or do-it-yourself food testing kits.

Miscellaneous: food pills, innovations from space research

The idea of food pills goes back to 1930s science fiction. Although there are a lot of food supplements being sold today, their effectiveness is much disputed and none of them is intended as a complete long-term replacement for food. This is due to the fact that the nutrients work in different ways if they are consumed within real food or just taken separately in form of pills. Real foods contain many other substances that for example help vitamins to work in the body in the desired way. Further scientific knowledge about metabolism, the workings of the human body and the interplay between different food ingredients could, however, make possible new forms of food pills and meal replacement drinks that take into account this complexity of different ingredients. Although they might not become popular with the mainstream, for the military, astronauts and emergencies the idea of innovative food pills could become a useful idea. Especially the military (e.g. DARPA) does extended research on “food pills”.

3.5 New markets due to societal developments

Lifestyle and market diversification

Foods and drinks can be necessities (basic foodstuffs having very inelastic demand curves) but also luxury goods (think of champagne, caviar, or luxury restaurant meals, all having rather elastic demand curves and higher income elasticities). Food and drinks consumption in today’s modern society are very much linked to lifestyles.

A very plausible future development would be the continuation or even further increase in existing market segmentation and diversification, with an even greater variety in consumption patterns and different lifestyles ‘co-existing’: traditional food and drinks alongside with convenience-oriented and ‘alternative’ natural and organic products, and niche markets such as ethnic and exotic, low carb, anti-fat, anti-aging and best-aging foods and drinks (e.g. Trendstudie Food by ZMP/CMA, 2007; see also Müller, 2007). Chilled food (high quality, cooled products with a short lifetime), regional food, health and convenience foods are the big trends, also for the future (ZMP/CMA, 2007).

Another driving force on the consumer-side is the so-called LOHAS-movement, shirt for Lifestyle of health and Sustainability that gains international popularity within Europe, Japan and the US. Although no official statistical material is available, estimations talk about 20% of the US population, up to 44% of Germans and around 29% of Japanese identifying themselves as LOHAS. The movement is currently growing and spreading and encompasses many of today’s popular concerns and lifestyle choices about health, human and animal rights, the environment and spirituality. Since it is a rather young phenomenon, around 10 years old, it is currently difficult to predict if it will last, disappear (e.g. just being a hype) or merge with or transform into something different.

With the current trend of lifestyle diversification continuing, the range of products is likely to broaden. The large food and drinks manufacturers will very likely try to aim at the mainstream life-style segments and concentrate on general health and wellbeing and convenience with a greater attention paid towards natural ingredients and allergy concerns if the current trends continue. Traditional, regional and “ethnic” foods are currently mostly provided by smaller companies and specialty producers. If the mainstream interest in such products will grow, possibly strengthened by immigration, larger companies are also likely to offer according products. This observation can already be made with Chinese, Indonesian and Indian food in, for instance, the Netherlands. Vegetarian products, halal food (suitable for Muslims) and products fitted towards different life-style groups – from ‘naturalists’ to ‘emerging-technology advocates’ – are likely to further evolve and grow as niche markets.

Demographics – an ageing society

The share of Europeans being older than 65 will rise from 16.3% in 2010 to 20.8% in 2025 and the share of people being older than 80 will rise by 1.1% within this time. At the same time, the share of children from 0 to 4 years of age will decrease by 0.4% during this period in Europe. Above this, there will be a slight population decline in Europe from 2010 to 2025 (UN population statistics). These demographic developments will lead to changes in consumer structure with a greater proportion of elderly and a declining number of babies and toddlers. Food producers need to adapt towards these trends that will become even more pronounced as time progresses. Since elderly need different nutrition than younger people due to changes in metabolism and physical characteristics, it is likely that the industry will also adapt and offer tailored, more customised solutions to elderly. Greater concerns about aging could also lead to changes in habits like healthy eating, dieting or caloric restriction.

Open innovation

The strategic co-operation with firms and institutions that can provide complementary skills and the integration of outside knowledge could help the food and drinks manufacturing industry to innovate and solve the prevailing problem of lacking highly qualified personnel. Experiences with interdisciplinary clusters where food and drinks companies operate in close proximity to universities, research institutes and other areas like biotechnology, health and ICT have gained positive results. (More information about clusters and networks can be found in the report on “Patterns and Performance of Sectoral Innovation”).

The knowledge-bio-based economy

The food and drinks sector is a large and important part of the European bio-economy. Innovations in this sector can be seen well within the goals and objectives on the European-Bio-Based-Economy (KBBE), which is defined as “transforming life sciences knowledge into new, sustainable, eco-efficient and competitive products” (“Cologne Paper”, 2007). The realisation of the goals requires a strong support for promoting science and research and attracting young people to work in these areas. Currently the situation still seems far from optimal and many industries are talking about a lack of engineers and declining numbers of students in bioscience and engineering. A major necessity that has been identified at the 2007 conference ‘En Route to the Knowledge-Based Bio-Economy’ hosted by the German Presidency of the Council of the European Union is the improvement of knowledge transfer. “Brain Drain”, i.e. the emigration of European scientist to non-European countries is also a problem to be addressed (“Cologne Paper”, 2007).

Consumer sensitivity

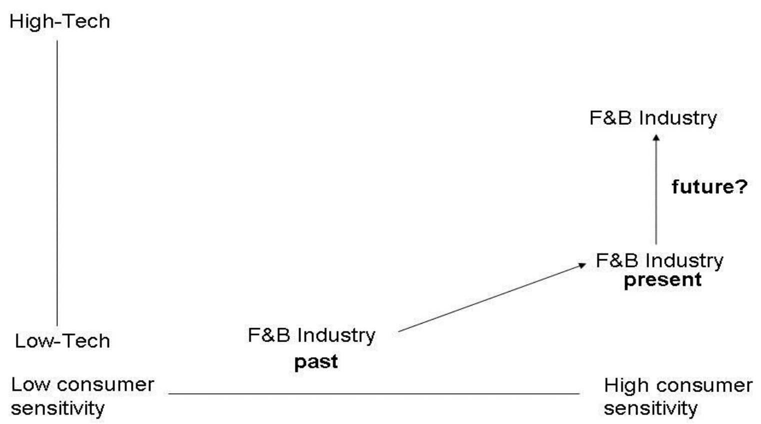
The food and drinks sector is rather unique. Some of the S&T possibilities that could provide solutions for demand-side wishes may just not be acceptable to the consumer. For instance, although many consumers want allergen-free foods, GMO may not be accepted as a solution. Nanotechnology could provide methods for better food safety, but is at the same time regarded as a food-risk itself.

High consumer acceptance is however expected from personalised diets and methods for improved food testing and food-chain surveillance and management. Already today, one can find innumerable personalised-looking advises for healthy eating and nutrition, although many of them do not seem to be evidence-based. The generally increasing knowledge about the workings of complex bio-systems and the role of nutrition will very likely contribute positively towards the general goal of producing safer, healthier and even tastier food based on scientific analysis.

social, cultural and religious aspects are also very important in the area of eating and drinking. Many religious or social rules have strict prescriptions about what (and even when) and what not to eat and drink (e.g. vegan, kosher, halal, ban of alcohol and wine etc.) and how to prepare food and drinks (e.g. in regard to butchering). Eating and taste preferences are also related to culture, e.g. in regard to spices, sweetness and the consumption of certain foods like insects (entomophagy) or specific kinds of meat (e.g. snails, frogs, crocodiles, camels etc.).

From past to present, consumer sensitivity and awareness has increased much, whereas the food an drinks manufacturing industry is currently still defined as low-to-medium technology (Hirsch-Kreinsen, 2006, 2008). In regard to expected (future) scientific and technological possibilities, the food and drinks industry could develop much further towards the characteristics of a high-tech industry, getting more similar to the biotech industry. If one categorises industrial sectors along the dimensions of technology (high technology vs. low technology) and “consumer sensitivity”, i.e. do ethical and safety considerations play a great role in regard to products, one could derive the following simplified structure:

Figure 3.6 Development of the food and drinks industry – from low to higher tech



In how far especially SMEs can perform this shift, remains very questionable, however. For firms that produce traditional foods and drinks which by definition cannot make major alterations in regard to ingredients, sourcing and production methods, organisational innovations and networking are and remain of major importance (e.g. Kühne et al., 2007).

The important question is in how far consumer sensitivity about the safety of food and drinks products and new knowledge about nutrition and their health effects can be brought into line with each other. Is the industry able to take up the consumer interests and the inputs from scientific research to develop successful new products?

Innovation and technology as chance

Although some technological developments may not become popular with consumers, there seems to be much room for innovativeness, although the trajectories may be different of what has been thought of in the past about the future, e.g. GMO and food pills. There seems to be much room for improvement in efficiency and sustainability within food manufacturing, which applies to large industries as well as to smaller businesses and organic production. Energy efficiency, a better understanding about how food works in the body, analysing the function of natural ingredients for preservation, taste, texture and health benefits, improved labelling and packaging to indicate spoilage when it occurs (preventing good food from being thrown away and spoiled food from accidentally be consumed) and ways to establish more trust between consumers and producers can be named as some major issues. There can also be innovation without GMO and adding synthetic nanoparticles, whereas modern biotechnology, genetic science and nano/molecular-sciences can nonetheless play an important role in agriculture, theoretical food science and food control.

4 Barriers to innovation

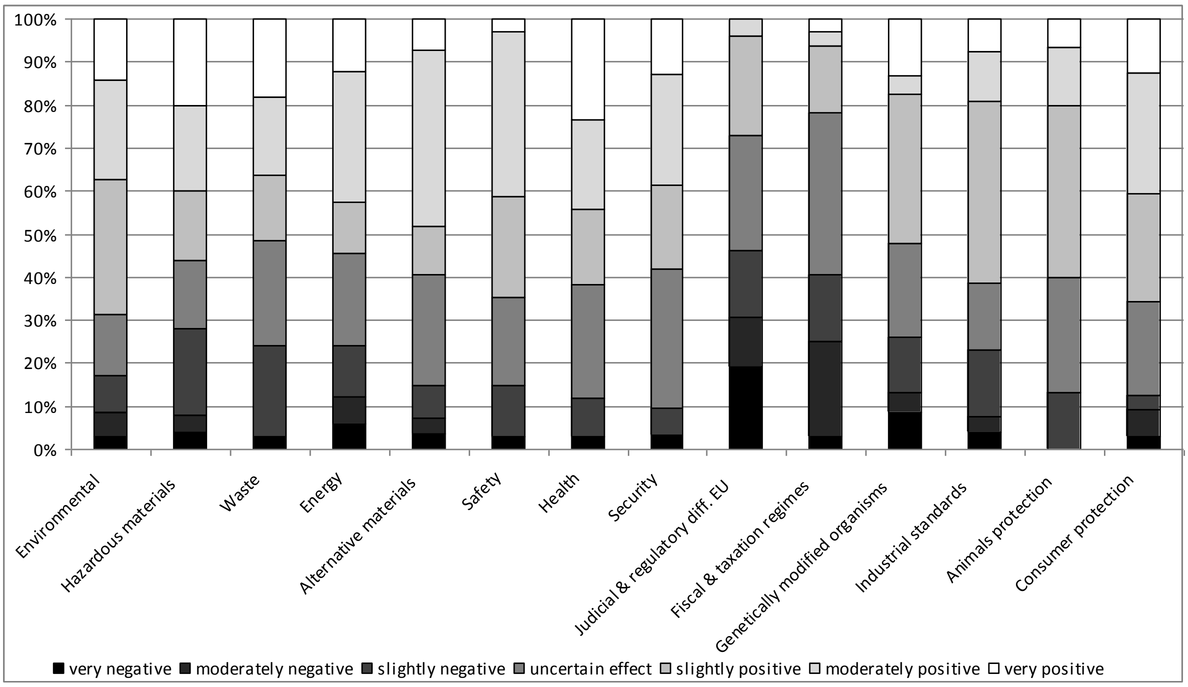
4.1 General findings from the survey analysis

Regulations and innovation

According to the literature, regulations mainly focus on human safety, food safety, health, and quality issues which puts the food industry in a similar position as biotechnology and pharmaceuticals. Next to regulations with positive effects, the literature also identifies regulations related to the environment, hazardous materials, waste, energy, and alternative materials as drivers for innovation in the food industry, while price regulations and regulations concerning genetically modified organisms (GMOs) are seen as barriers.

The SIW-II complementary survey verifies most of the above claims, accentuating health, safety, environmental and alternative material and waste regulations as drivers. In addition to this, we identified security regulations, industrial standards and consumer protection regulations having a positive influence on the industry’s innovation activity. While we could not confirm the negative effect of price and GMOs regulations (neutral to slightly positive), we discovered fiscal/taxation regimes and judicial/regulatory differences across Europe as major barriers. Is important to notice that in general regulatory pressure was perceived lower in the past and is expected to continuously increase over the medium- and long-term.

Figure 4.1 Effects of regulation on innovation - food and drinks

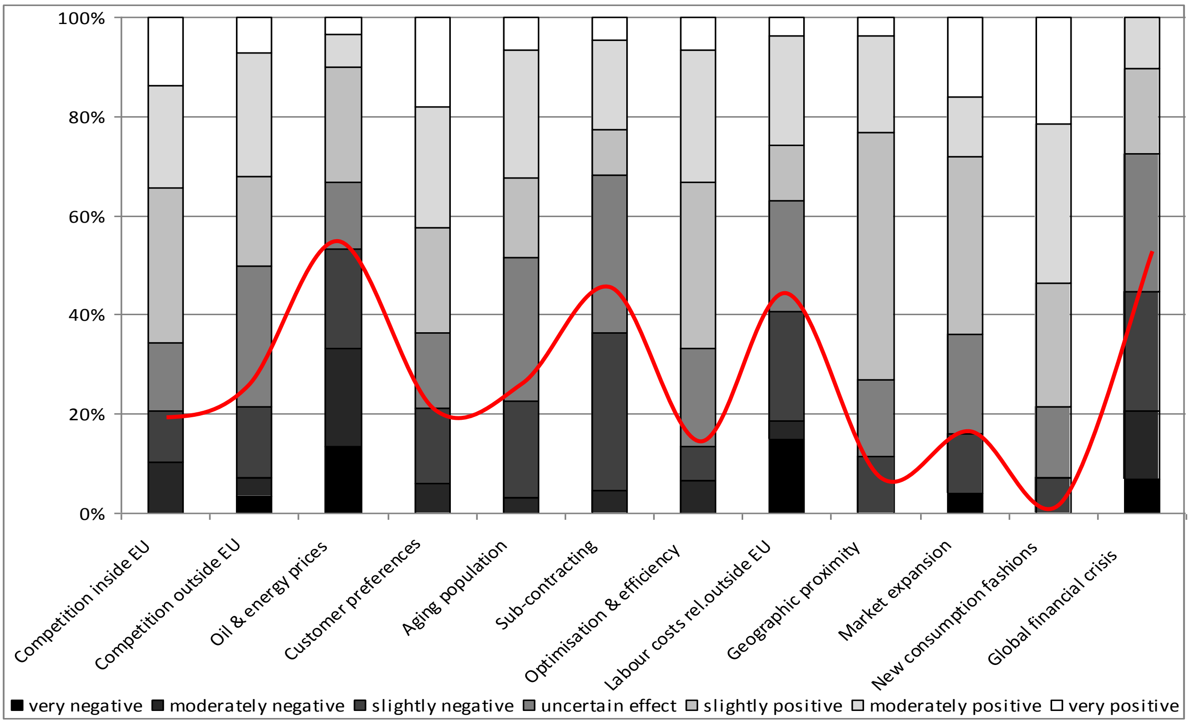


Highly significant and correlated relationships between communication regulations and innovations in manufacturing methods can be identified. The same holds for occupational regulations and innovations in supporting activities. Furthermore, positive moderate correlations exist between most of the above drivers and service innovations. In addition to this, service innovations are positively related to REACH, labour and agriculture regulations. Pre-emption of regulatory risks has also a moderate positive effect on service innovation. Food companies seem to innovate in order to avoid the pressure of possible future regulations. But the found effect could also be interpreted that companies exceed current regulations and standards to create a better firm and brand image, since previous research shows that consumers are increasingly concerned with environmental and health issues regarding food products, which also influences their purchasing behaviour (INNOVA, 2008). Finally, according to literature, the harmonisation of rules aims to ensure fair competition and promote innovation in the area of food (ETP 2007), while competition regulations in Europe shows no significant effect on any innovation type.

Literature highlights the positive effect of competition originating from inside and outside of Europe, sub-contracting and geographic proximity on innovation. Especially open innovation and the growing interest in buying or licensing innovations made by other companies instead of relying solely on own research, is becoming more attractive for the food industry (CREME 2008). Furthermore, the industry is very much demand-driven (Aslesen, 2008), giving customer preferences and new fashions in consumption (e.g. organic and functional food) an important role in stimulating innovations (Flexnews 2008, INNOVA 2008). Related to the previous point, the financially well-off aging population is regarded as a main driver from the demand side (Flexnews 2008). Concerning innovation barriers, oil and energy prices and cost of labour in Europe are the main issues hindering innovation.

The survey supports the literature to a large extent by identifying competition, geographic proximity, customer preferences, and new fashions in consumption as main innovation drivers and oil/energy prices as the main innovation barrier. While we could not confirm the positive influence of sub-contracting and the negative influence of labour costs in Europe on innovation in this industry, we find a positive effect of market expansion and a negative impact of the global financial crisis. Furthermore, the market pressure in general was always high and is perceived to intensive in the future.

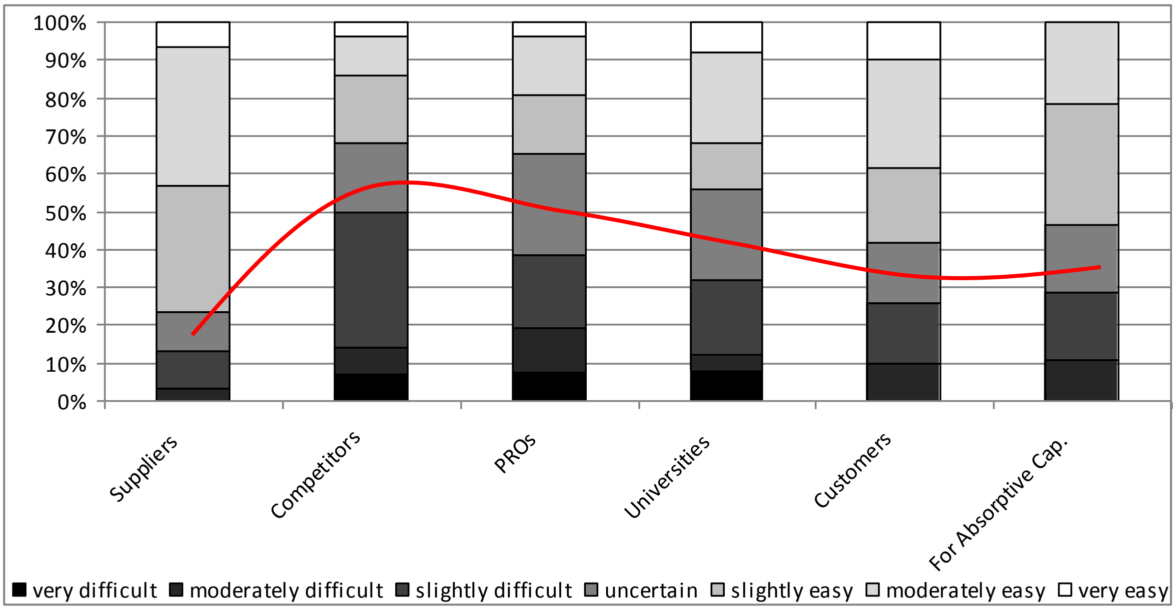
Figure 4.2 Effects of markets on innovation



Taking a look at the correlation analysis, the incumbents current market position is highly significant and highly positively correlated to innovations in services, manufacturing methods and design. This stands in contradiction to the literature which states that SMEs in the food and drink industry see market dominance by large firms as a factor that impedes innovation. The pace of innovation and the relocation of manufacturing and business activities are also highly correlated to innovations in management systems and moderately related to innovation in supporting activities.

Collaboration and open innovation are perceived as generic innovation drivers for all industries. Regarding the food industry, the literature highlights that the growing necessity of and interest in buying or licensing processes and innovations made by others instead of only relying on in-house R&D, is becoming more attractive (crème 2008). Especially collaboration which ensures complementarities of innovative capacity and know-how seems to have a large positive impact on innovation. But the literature fails to explain which specific collaboration partnerships are the most promising ones. The survey confirms that for the food industry collaborations related to absorptive capacity have a positive effect on innovation. But more important, the results suggest that collaboration with suppliers and customers are perceived positive by respondents in regard to how easy it is to work together. On the other hand, cooperation with competitors and public research organisations (PROs) are more difficult to engage in and thus are perceived as negative in respect to innovation activities.

Figure 4.3 Effects of collaboration and open innovation on innovation



Furthermore, the correlation analysis identifies highly significant, highly correlated relationships between service innovation and collaboration with suppliers, PROs and universities. This means that, no matter of positive or negative effects, collaborations are only related to innovation in services, while leaving all other types of innovation unaffected.

4.2 Market factors affecting innovation

Consumer demand: preferences and uncertainty over future demand

Consumer sensitivity towards and acceptance of innovations in food and drinks play a distinct role in innovations. This especially holds for science and technology (S&T) solutions and applications which in the end might or might not be acceptable to the consumer. For instance, although many consumers want allergen-free foods, GMO that can provide allergen-free food often are not accepted as a solution. Similarly, nanotechnology could provide methods for better food safety, but is also seen as a food-risk in itself.

From past to present, consumer sensitivity and awareness has increased much, whereas the food an drinks manufacturing industry is currently still defined as low-to-medium technology (Hirsch-Kreinsen, 2006, 2008). In regard to expected (future) scientific and technological possibilities, the food and drinks industry could develop much further towards the characteristics of a high-tech industry, getting more similar to the biotech industry. But the question remains, in how far consumers and regulators are willing to accept certain kinds of innovation. Especially the experiences with and reactions to GMO and nanotechnology-based ingredients are showing that caution is needed with innovations in foods and drinks.

Consumers represent a very wide spectrum of interests in regard to choices for food and drinks. It is also difficult to predict which information customers will believe and which trend they will follow. Also advances in science, especially within new and emerging areas, could lead to fast revisions and updates of findings and information. Taken together, this situation necessitates an agile and flexible industry and ditto diversification strategies in order to be able to react fast towards consumer interests and new scientific discoveries.

SMEs, and especially small companies, are at a disadvantage and generally encounter more challenges in performing the necessary research and development, legal assessments, and market and consumer studies that may be needed to act pro-actively in regard to innovations for food and drinks. Large companies have a much higher competitive advantage as also CIS IV/Eurostat data reveals: the 0.86% large companies with 250 or more employed persons generate 93.05% of the sector's turnover.

Supply / technology push and demand pull

Functional foods

Although functional foods and drinks are valued by many consumers which is also reflected in a variety of products that claim to be beneficial in regard to wellness, fitness, health, 'vitality', 'energy' etc., new EC guidelines require "that any claim made on foods' labelling, presentation or marketing in the European Union is clear, accurate and based on evidence accepted by the whole scientific community". While this certainly is positive for consumers and can spur innovation, challenges are expected in increasing costs for research, development and the scientific evaluation process.

The new obligatory EU-regulation includes a EU-wide harmonisation of standards and makes the assessment of every health claim by the European Food Safety Authority (EFSA) and there are transition regulations for already existing products and health claims. Health claims as well as products are being assessed and when the transition period is over, only approved health claims will be allowed to be used. If the products will not meet the (scientific) standards of the health claim, it will not be allowed on the market bearing this claim after the respective transition period is over (e.g. Van Zoest, 2009). Only if the product complies with certain guidelines and limits (e.g. percentage of fats and vitamins), it is allowed to be (explicitly) advertised as healthy. Statements like "calcium is good for your bones" are only allowed if approved on a so-called "positive list". Claims about the prevention of illnesses, i.e. "this product prevents the risk for heart disease" or "this product improves your memory" are not allowed, except if scientifically proven, which necessitates medical testing procedures.

Although health claim regulation has been criticised for setting restrictions to advertisement, the intention behind it can be regarded as positive since it encourages producers to compete in establishing real improvements and innovations and prevent fraud. The health claim regulation is also seen as a reaction to customers' wishes to get a clearer differentiation between objective information and advertising claims, and hence improve the consumer choice process. However, looking at the expected higher costs and uncertainty that are involved in the new development of scientifically evaluated functional foods can cause industries to decide to stay on the 'safe side' instead of investing in R&D for functional foods and drinks with uncertainty about market approval. The new health claims regulation will make it especially difficult for small companies to produce and sell functional foods or products with a health claim, because of the necessary amounts of scientific research and evaluation that have to be conducted.

Medicinal food

Even more challenging than the development of functional foods is the idea of medicinal foods. In policy and legislation as well as in the minds of (European) consumers there is still a demarcation line between food and medicine. “Medicinal food”, i.e. food and drinks products that ought to have a (proven) therapeutic effect in regard to an illness fall into a kind of “legal hole”, since they either have to be defined as medicine and have to undergo pharmaceutical testing or as food or drinks, which are not allowed to be marketed as medicine , Although their development may be technically possible, real medicinal, i.e. food with the real effect of medication would actually not be allowed in Europe to be sold as foods or drinks outside a formal medical context (i.e. hospitals).

But also so-called nutraceuticals, i.e. foods or drinks with (proven) therapeutic effect which, however are not defined as medicine pose a problem in regard to European regulations and definitions. They are neither ‘normal food’ nor medicine but may actually go beyond ‘functional food’. These challenges in regard to definition and regulations may show that the spectrum from ‘normal foods’ to medicine may be rather a continuum than a discrete ‘either-or’ definition.

Substitution of unhealthy ingredients

Replacing unhealthy ingredients with healthier ones may sound not too difficult, but could not only pose economic challenges but also technical ones. Nearly every ingredient in foods and drinks serves a specific purpose necessary for providing the desired taste, texture, smell or shelf-life. Because of this, even the reduction of “unhealthy” ingredients like fat, sugar or salt and the substitution of ‘synthetic ingredients’ through ‘natural’ ones in foods and drinks can be very challenging and necessitate much scientific research, experimentation, know-how and high-level skills in areas like physics, chemistry and biology. In some cases a substitution of ingredients could even be comparable to re-inventing a whole product. Only large companies are likely to have the necessary financial means and human resources.

Above this, the distinction between ‘natural’ and ‘synthetic’ is not always easy to understand and leads to confusions within industries but also with consumers (e.g. in regard to glutamate).

Personalised diets

Since the analysis of biological systems and the interaction of different proteins and other substances is a very complex field, it may take some time to yield usable results. Innovations and the integration of according knowledge are likely to occur step-by-step as new insights and discoveries are being made and can be transformed into workable products. Currently there already exist many claims, offers and advises for personalised diets, which however still lack a solid scientific basis. Epigenetics is still an emerging research field and normal genetics is sill far from full understanding. However the interest of customers, researchers, food producers and policy makers is currently high so that such research areas are getting quite good support. However, although the technology for genetic sequencing gets increasingly cheaper, there still exists a lack of knowledge about the right interpretation of genetic data and the development of reliable and useful personalised strategies on that basis. Reports about the offer of personalised nutrition and genetic analysis have to be viewed with much caution at current time.

Food pills

As research about food supplements suggests, there seems to be a big difference between foods/drinks and pills in regard to their nutritional utilisation in the human body. Since eating is to a great deal a social activity, food pills may not become popular with the great part of the population out of cultural reasons.

Even if food pills with sufficient nutritional value and functionality would be developed, many people may not opt for this choice (at least not as their major choice) since eating and drinking is not only about nutrition but more importantly also has a social value and relates to psychological aspects, wellbeing and quality of life.

GMO food

Although scientific studies seem to be inconclusive about the real danger of genetically modified organisms (GMO) to humans and the environment, GMO is quite unpopular with a considerable share of the European population, especially in regard to agro-food products. Even in the generally technology-friendly Japan, the Japanese “NO! GMO” activist group has joined forces with international like-minded organisations and the Japanese opposition to GMOs is very strong for an Asian country. At the same time, the popularity of organic food is huge in Europe (and steadily increasing in Japan).

Even the so-called “golden rice”, a genetically modified rice species developed by scientists from ETH Zurich and University Freiburg/Germany that produces and contains Beta-Carotene (pro-vitamin A) has led to heavy controversies, especially in Europe (Mayer, 2005). However, GMO research is continuing with the goals of producing plants that contain (more of) specific ingredients attributed to positive health effects (e.g. vitamins, calcium etc.). The prospects of future GMOs in agro-food products will mainly be dependent on consumer perception and regulatory issues. Both of them can also be mentioned as the major hindering factors to related innovations. (The use of genetic technologies for plant analysis to select plat derivates with certain characteristics to be selected and used within normal breeding-processes gets much more acceptance, however).

Since different countries have different attitudes towards GMO, global sourcing may pose a challenge. The GMO issue also provides a good example for the interlinkages and dependencies throughout the food chain and the importance of choosing suppliers and trusting them.

Cultured meat

In technological terms, currently known methods for cultured meat are still too inefficient for profitable commercial usage. But this may change as the technology will be conducted more routinely and in larger scales and when tissue and stem cell technologies will mature in general. However, even if the technology matures, it is very likely to be far more expensive than conventional production at least in the beginning.

Although cultured meat comes with many advantages that include the cultivation in controlled and clean laboratory conditions which eliminates the risk of disease and use of antibiotics and growth hormones, the possibility of engineering the fat amount, no need to kill animals for food and a reduction of environmental pollution caused by animal farming (which according to the UN FAO is higher than that produced by the transport sector (FAO, 2006), many current customers however show negative (emotional) reactions towards the idea. Even the moderator of a German ZDF science documentary ("Abenteuer Wissen" from July 8, 2009) has voiced his scepticism about artificial (cultured) meat and his preference for the natural product. But it is likely that the reaction of customers changes when they are really beginning to rationally compare current meat production with the envisioned future method. Therefore the question remains how to convince consumers about the advantages of cultured meat and to pay higher prices for potential products.

Here technical and economic challenges are expected to be solvable in the short- to mid-term; however consumer scepticism exists and if consumers do not accept cultured meat, its production will not have economic value.

New food: insects and other species

Eating algae, worms and insects represents a very uncommon practice for most Westerners and the highest barriers may be social and psychological in nature. However, algae is already being eaten as Japanese culinary in sushi and processed worms and insects that do not look like insects and worms anymore may even get accepted if one considers that most people also do not think about the chicken, cow or pig when eating ham and sausages. The main challenge for bringing insect products into the shelves of European food stores is cultural and psychological in nature.

Nano-based food and drinks ingredients

Although the usage of nanotechnology could bring about many new food creations and experiences as well as functional food (e.g. encapsulation, targeted delivery or time-released distribution of nutrients) Consumer protection and advocacy groups are already raising concerns over possible negative side effects of nano-particles in food. Since the technology is novel, there exist insufficient long-term data about potential problems. As of 2010, particle size as such (e.g. nano-scale vs. non nano-scale) is not considered within the European novel food regulation and food assessment criteria, although the major aspect of nanotechnology is that substances of a specific kind show different properties and reaction capabilities if nano-scaled or not. Another important issue that is seen as an advantage in medicine for treating brain diseases is that nano-particles can cross the blood-brain-barrier. In other situations, i.e. food and drinks, this property could increase the occurrence of dangerous and unintended effects. However the European Parliament recently voted for mandatory labelling of foods that contain nanoparticles.

On the one side the food and drinks industry is quite interested in the new possibilities of nanotechnology, but on the other hand it acts quite cautions on this, because of uncertainties about perceptions and (future) regulations.

Healthy food

Especially in the context of obesity and related health problems, the call for generally healthier food in regard to fat, sugar and salt is large and coming from policy makers, health professionals consumer groups and consumers alike.

The food and drinks industry is (partially) held responsible for the problem of obesity, whereas the question arises if this is due to lacking technology and know how, due to price competition or due to lack of good will. And if latter would really be the case one could ask in how far regulations like compulsory labelling or changing consumer demands, e.g. in relation to healthy living/aging could provide necessary incentives for change and innovation. In regard to pricing, it may be necessary to think about reasons why unhealthy foods and drinks may be cheaper than healthy ones and perhaps reconsider pricing schemes by also taking into account secondary costs like health increased costs in relation to obesity and unbalanced nutrition. However if looking at people who practice caloric restriction and CRON diets, the view of holding the industry solely responsible for obesity may be disputable. On the other hand, if looking at the objection of many food industries against the new labelling system (“traffic-light”) that makes it easier for the consumer to see how much sugar, salt and fat a product contains, the questions arises why the industry has something against more transparency.

Eco-packaging

The call for environmental sustainability has made the idea of bio-degradable packaging (e.g. biopolymers, bio plastics etc.) increasingly attractive. However, their use for the food industry is only limited, because these materials which are derived from living organisms (that once had pores), cannot be sealed air-tight. Above this, they are not very heat resistant and decompose rather quickly. This does make (non-synthetically enhanced) biopolymers unsuitable for liquids and products with a long shelf life.

Supply: lack of staffing and skills

The lack of sufficiently is mentioned by the food and drinks industry as one significant hindering factor for innovation. Currently, however, many European food and drinks manufacturing industries, perhaps as many as half of them (IFST, 2006), are experiencing a shortage in scientific and high skilled personnel (CIAA, 2008).This problem is also observed globally. Even innovations that do not require new high-tech applications and focus on tackling issues like healthier nutrition necessitate specialised knowledge and skills. A German meat technician, for example, was only able to realise his innovative idea about a fat-reduced sausage with the help of scientists from the Fraunhofer Institute that also supported him in the following marketing process. Also a growth in regulations and socio-ethical and environmental considerations makes food and drinks production more and more into an interdisciplinary subject. Therefore innovativeness could become a real problem for the sector and many potential improvements might just not be possible due to lacking human resources.

4.3 Regulation and innovation

Safety, ethical, ecological concerns

Food and drinks manufacturing and consumption are a very sensitive topic, e.g. in regard to safety, ethics, ecological responsibility and ditto regulations. Many different actors (organizations, organized interests) can directly or indirectly influence innovation activities, by raising their voice (protesting, banning), voting by the feet, i.e. through actual consumer or actively calling for new products and innovation as a result of laws and regulations (e.g. by banning certain ingredients or processing methods).

The major stakeholders in food and drinks often have quite different opinions, which can make mutual trust and cooperation challenging. For many consumer, environmental and animal welfare organizations, food regulations often do not go far enough, whereas for some parts of the industry and for researchers many precautionary demands seem to be too strict, form a barrier to innovative behaviour and in some cases lack a sufficient scientific basis.

Even researchers themselves often disagree, e.g. over the safety evaluations of GMO and certain ingredients, which makes it difficult for regulators and consumers to have a reliable basis for their decision making. Such uncertainties in regard to assessment, regulations and consumer acceptance can make at least certain types of innovation (i.e. more technical and 'radical' ones) less attractive for food and drinks manufacturing industries to pursue.

Protection of Intellectual Property Rights

Intellectual property right seem to remain a challenge for the food and drinks industry because recipes that for example only effect taste but have no other functional property (i.e. being useful, novel or non-obvious) but are nonetheless crucial for the distinction and economic success of foods and drinks products are not patentable in many cases. Many food/drinks recipes do not fulfil the criteria of being useful, novel and non-obvious which are the necessary criteria for being patentable. Obtaining other forms of intellectual property rights protection (e.g. copyrights) for food/drinks products can also be difficult.

5 Horizontal issues

5.1 National specialisation

The link between economic performance and innovation in the food and drinks industry exists but is less clear than in many other sectors. Not all innovative ideas, technologies and innovations in food and drinks manufacturing are readily accepted by consumers or regulators. This holds for technologies such as GMO and nanotechnology, but also, to mention another example, for “high tech” or “synthesized” ingredients. Also, some food and drinks products that are being manufactured in traditional ways and without (significant) changes, sometimes over centuries, still appear to be much valued by customers and generate high economic profits.

A similar situation applies to patents since many products within foods and drinks do actually not formally qualify for patenting and are thus protected by other means like trademarks, “petty patents”, recipes or simply trade secrets. *Kentucky Fried Chicken*, for example uses elaborate and high tech procedures to guard its multi-million secret dollar recipe. Food and drinks typically is a sector which combines a low global patent growth rate with a high technological specialisation pattern.

Statistics on patents or high tech applications may not necessarily say something about the economic performance (‘success’) of food and drinks manufacturers. On the contrary even: the absence of high tech can still generate a successful firm and successful products. Also the relation between the intensity of technological applications and export success does not necessarily apply to the food and drinks manufacturing industry since also traditional, low tech produces products can be very successful in regard to exports and be viewed as local or regional specialities (e.g. traditionally produced Parma ham, wines, cheese, beers, chocolates etc.).

Especially large food and drinks manufacturers are much dependent on technological improvements, especially in regard to production efficiency as well as quality control and hygiene. In large companies, automation also plays a much more important role than in small(er) companies or firms that produce traditional specialities often even in a “hand made” manner. However, technologies that relate to food processing and agricultural machinery and apparatus actually do not count as food and drinks manufacturing and hence are not considered here in regard to national specialisation.

Economic and technological specialisation

Economic specialisation is usually measured by relative comparative advantage (RTA), builds on economic variables such as employment, value added, import and export. Total Factor Productivity (TFP) which indicates the output of economic activities taking into account the amount of capital and labour inputs that are used. TFP measures the value added per unit of input and indicates the portion of growth in total economic output (value added) that is not explained by the quantitative growth of the most important inputs. It therefore captures all those elements that make the inputs more productive. TFP is importantly linked to innovative behaviours, as innovative processes tend to reduce the amount of inputs for a given output level. TFP growth is thus interpreted as capacity to turn technological efforts into more efficient production activities and ultimately to higher wealth (i.e. more value added per unit of inputs).

Technological specialisation describes the sectoral profile of a country's technological portfolio, composed by patents across sectors. From this the specialisation index or Relative Technological Advantage (RTA) index can be derived, defined as the share of a sector in a country's total patent output in relation with the share of this same sector over world total patent output.

The food and drinks sector shows positive but relatively low average TFP growth rates. On average the TFP annual growth rate was somewhat above 0.4% during the period 1979-2002 which is higher than the construction, personal services and pulp sector but considerably lower than all other sectors (Grupp et al., 2010: 37). According to Europe INNOVA SIW research on national specialisation patterns, most of the EU 15 countries have gained comparative and technological advantages in the food and drinks sector, especially so Denmark, Italy, Spain, and the United Kingdom. Denmark is highly specialized in this sector and can be seen as the technological leader and has a strong agglomeration and regional employment focus in food and drinks. Denmark is an example of consistent strong combination of technological specialisation as well as "high quality" of specialisation, not only in food and drinks but also in the field of biotechnology. Since the 1990s Greece and the Netherlands has also become highly specialized in this sector. In contrast, Austria, Germany, Luxembourg, Sweden and Portugal have strong technological disadvantages in the food and drinks sector.

Measured in terms of patents and patent citations, the Netherlands, Spain and Belgium show high scores, but Denmark leads, with an excellent combination of relative technological advantage and high-quality of innovation activities. Of the new Member States Hungary and Poland show the highest share of patents (Grupp et al, 2010). However, as already mentioned, greater technological specialization in food and drinks does not necessarily correspond to greater innovativeness. For example, Spain is strongly specialized in this sector, but it ranks average or even below in the success indicators for innovation. This is likely due to the fact that innovations in this sector are typically less knowledge and technology-intensive than in other more R&D-oriented sectors. Traditional regional specialities can be economically very successful.

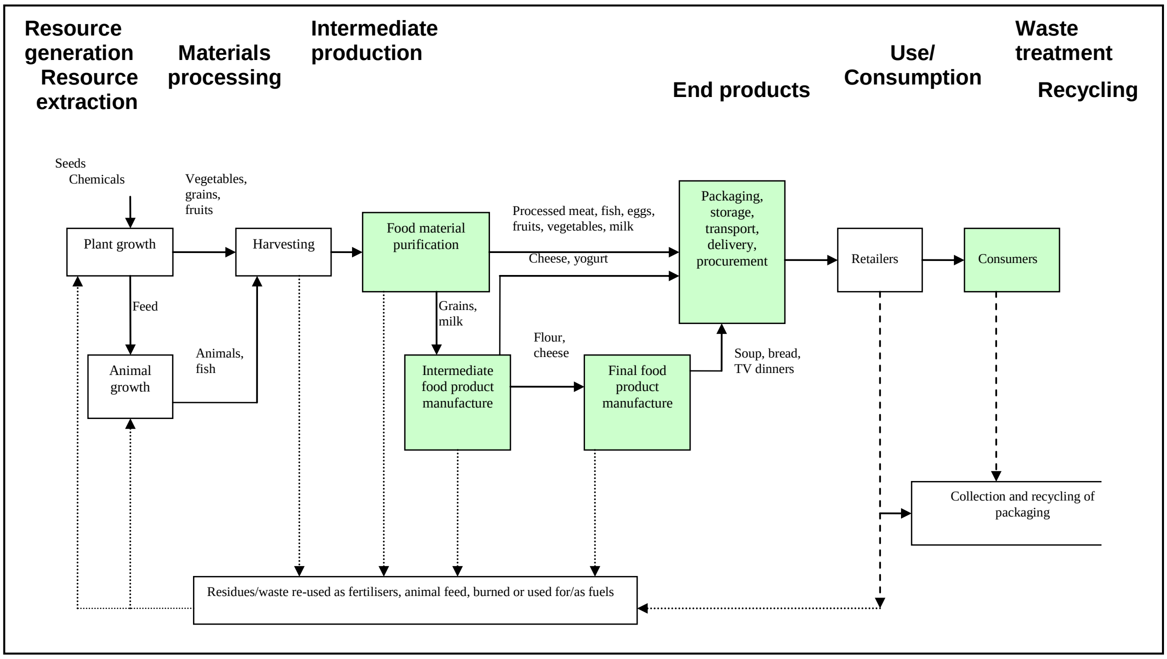
5.2 Eco-innovation

In regard to the manufacturing of food and drinks products, many activities that relate to eco-innovation are actually located more upstream and downstream of the value chain, i.e. in agriculture, food testing, transport and sales (cf. Banse, Kaditi et al. 2008), which belong to other NACE codes than manufacturing of foods and drinks (NACE DA15 / NACE C10 and 11 on Rev. 2).

Especially agriculture and animal farming can contribute negatively in regard to energy consumption, carbon dioxide / greenhouse gas emissions and water pollution. Also transport contributes its share, as the growing consumer concern over so-called food miles is also reflecting. But the food miles issue also relates to consumer choices, i.e. whether consumers prefer to buy local products and are considerate about food miles, or whether they nonetheless prefer to buy products that got imported from afar. If we take bottled water as an example, which is quite popular with consumers (including health oriented ones), we observe, however, significant negative environmental impacts including energy consumption for processing, cooling, transport and bottling, health risks and environmental pollution (bottles) and problems in regard to ground water and water availability (National Geographic, 2010). Some policy-makers, e.g. in the US, have already reacted and banned the sales of bottled water in local supermarkets.

In regard to the processing of foods and drinks themselves, the amount of different operations and final products require different levels of intermediary processing (e.g., minimal processing of fruits vs. substantial secondary processing of dry cereals). In essence, most of the physical operations of this industry are rather similar for most of the production processes involved. This is particularly true for separation, cleaning, cutting, crushing, blending, grounding, and packaging methods. Chemical and biological operations do differ – which often share basic principles with those in the chemical and biotechnology industry. These operations are related to fermentation, homogenisation, hydrogenation, curing, drying, pigmentation, and conservation. In addition, and in spite of its controversial perception in Europe, irradiation processes for food preservation have been used for quite a while (especially in the US). Finally, we have the processes of meat packing, bottling, packaging, storage and food equipment cleaning and sanitising (Bralla 2006).

Figure 5.1 Value chain diagram for the food and drinks sector



Source: modified from Graedel and Howard-Greenville (2005)

Sustainability issues in the food and drinks sector can be related to several different fields, ranging from efficiency of the food production and consumption to health issues, from the local and seasonal food production to organic food, from the exhaustion of food sources such as fish population to energy consumption of different diets, etc. (Diaz Lopez, Tukker et al. 2008).

Energy consumption and climate impact

In terms of contribution to climate change, it is estimated that food and drink products are responsible for 20 to 30% of the various environmental impacts of private consumption in the EU25. The latter includes the full food production and distribution chain 'from farm to fork'. Meat and meat products are the most important contributors to global warming, followed by dairy products (Tukker, Huppes et al. 2006). The IMPRO-meat and diary study estimated that the four main product groups (dairy, beef, pork and poultry products) contribute respectively 33-41 %, 16-39 %, 19-44 %, and 5-10 % to the impact of meat and dairy products consumption in EU-27 on the different environmental impact categories (Weidema, Wesnaes et al. 2008).

The energy consumption of the food and drinks manufacturing industry ranges in the mid field of the most important industries. With a 10.87% share in energy consumption of the most important industries within the EU-25, food and drinks (and tobacco) manufacturing is ranked behind iron and steel, chemicals and petrochemicals, non-metallic minerals and paper and pulp production (IEA, 2007; data availability for 2004). However, agriculture, packaging, transport and retail also contribute to the final energy and environmental balance of food and drinks products

The food and drinks production requires different energy forms, such as electricity, process steam and thermal energy – which in most cases are produced from fossil fuels (Bernstein, Roy et al. 2007). The sector has traditionally been a large consumer of water, both of drinking quality and raw water. In both the food and drinks industries water of drinking quality is used as an agent of the manufacturing process and to transport raw materials in a processing unit. Raw water is used as wash-down water used to clean ingredients and equipment, and for heating and cooling purposes. In the wine industry, for example, 30 to 150 litres of water are used to vinify 100 L of must (unfermented grape juice).

Water consumption and pollution

The main environmental issues of the food industry are related to water consumption, waste water, high concentrations of biochemical oxygen demand, suspended solids and fertiliser chemicals, and greenhouse gases emissions derived from energy use (e.g., cooling and heating). Drinks sector environmental concerns are related to water use and greenhouse gas emissions. It has been suggested that the wastewater volume of "soft drink processes" is lower than in other food-processing sectors, but fermentation processes are higher in biochemical oxygen demand (BOD) and overall wastewater volume compared to other food-processing sectors (PA 1998a). Overall, the F&B sector is considered one of the largest producers of wastewater (Graedel and Howard-Greenville 2005).

According to the FAO cattle farming produces more greenhouse emissions than transport (FAO, 2006) and the water usage for foods and drinks manufacturing is substantial. According to data from the Global Development Research Center, the amount of "virtual water" (i.e. water being used for the production) in food products can be very great and goes mostly unnoticed. The food and drinks industry also accounts for considerable amounts of waste due to overproduction with the ready-meal and convenience sector as a main contributor (cf. T. Staikos, 2008).

Food waste and wasted food

The amount food that is being wasted and thrown away is huge in Europe. According to Henrik Harjula, principal administrator at the OECD "only 30 to 40 percent of produced in Europe ends up at your table" (DW, 2009). In the United Kingdom, where the problem is worst in Europe, 11.2 billion euro worth of food are annually discarded. Wasted food generates significant ecological (e.g. rotten food generating the greenhouse gas methane) as well as societal problems in face of hunger and starvation in developing countries.

Industries can counter the problem by e.g. using their food waste as energy source, but a considerable responsibility lies with the consumer by not purchasing more food than they consume. Especially if resistance to many preservation methods is growing, the consumers need to become more aware about the amounts they buy in advance. But also retailers can do their contribution, e.g. by better packaging methods (e.g. re-sealable) that better suits the consumption pattern of small and single households.

Finally, chemical agents are used at different stages of processing and alter the biochemical properties of waste streams (Graedel and Howard-Greenville 2005). Waste generation (organic waste, packaging waste) is a concern shared by both industries. Most steps in food and drink processing generate residuals, which typically go to waste and/or reuse for different purposes e.g., manures are used as fertilisers whereas general waste can be geared towards furnaces and ovens as fuel for energy generation (Graedel and Howard-Greenville 2005). A growing area which originates solid waste is related to packaging materials, which in Europe is required to be recovered by law.

Eco-innovation opportunities

From the review above it is clear that most of the prominent environmental pressures in the food and drinks sector come from their use of resources and waste generation. In addition, an increasing area of concern is related to human eating and drinking habits in terms to greening consumer choices. A clear related area is the provision, choice and selection of greener products. Recent studies highlight that current and emerging eco-innovation trends in the F&B sector focus on:

- the use of more sustainable resources (organic and/or regional food)
- sustainable food processing, eco-supply/network management
- more sustainable outputs (e.g., biomass energy)
- packaging and waste recycling (e.g., smart/eco packaging)
- monitoring of the food (e.g., intelligent labels)
- industrial processes (e.g., automation and monitoring) and eco-labelling

It is clear that most of the prominent environmental pressures in the Food and drinks sector come from their use of resources and waste generation. As a consequence, eco-innovation opportunities in this sector have a strong focus on sustainable manufacturing (e.g. zero emission systems, process automation, etc.).

For the food sector the use of more sustainable resources (organic and/or regional food), eco-packaging and waste recycling, and monitoring of the food (e.g. intelligent labels), are also particularly relevant for the food sector. The drinks sector is primarily focused on eco-innovations related to water and waste management and energy efficiency. Inherently, these options are more related to pollution prevention and good housekeeping of the production process. Waste management (e.g. organic waste), water reuse (e.g. in the wine industry), energy conservation, substitutes for restricted ozone depleting refrigerants in refrigerators, reducing bottling losses, inventory control, process efficiency, and zero emission systems are accounted here.

Energy solutions

Food and drinks manufacturers as well as retailers and fast food chains are already addressing this problem and seek put innovative ideas. Researchers at University of Birmingham, for example are developing ways to use chocolate waste for energy production (University of Birmingham, 2008) and Japan is promoting the use of food leftovers and residues from industrial processing for animal feeding and fertilisers. The use of leftovers as animal feed also comes with downsides in regard to hygiene and safety (IHT, 2008). Using leftovers as energy source, however, looks like a positive idea, especially in view of the growing popularity of regenerative energy sources. Bio-energy and renewable raw materials currently are popular new forms of income to farmers. However, the planting of crops that are exclusively used for fuel production directly competes with arable land use for growing food meant for human and animal consumption, and may hence lead to a substantial increase in relative prices of food and feed, if not to conflicts in the near future.

Laws and Regulations

The Integrated Pollution Prevention and Control (IPPC) directive (2008/1/EC) for minimising pollution from industrial sources was introduced to foster organisational and technological change in the food and drinks sector. An IPTS report suggested that this was the case in those areas where installations were not previously regulated. Noticeable positive effects were encountered in firms where management of environmental effects was (traditionally) high. The IPTS evaluation found that primary/front end measures have had a generally positive impact on productivity and plant performance, especially for plants with a strong environmental performance (Hitchens, Farrell et al. 2002). A study commissioned by the EC reports that depending on the sub-sector and regional differences process change may achieve different results but no mentioning is made to the effect on innovation (see e.g. Kotronarou and Iacovidou 2001). National evaluations of the impact of the IPPC directive do not treat the impact of this regulation on innovation beyond the adoption of best available technologies (see e.g. DEFRA 2008).

According to Fanckx et al. (2008) the Waste Framework Directive 2006/12/EC is expected to be an important driver for eco-innovation diffusion in the food and drinks industry – at least for waste management. Since the new Waste Framework Directive introduces an important new element on energy recovery through anaerobic digestion of biodegradable waste, it is expected that the introduction of technologies for co-generation could be speed up. The literature also reports that public intervention may constitute an important driver for eco-innovation in packaging. All Member States have set up return, collection and recovery systems for packaging waste. Most have adopted measures aiming to encourage the use of recycled material. According to Franckx, van Acoleyen et al. (2008) a negative point is that certain national measures and an incorrect application of the Directive have led to partitioning of the internal market, in particular in the drinks sector. The Commission foresees flexibility with respect to incentives aimed at encouraging prevention and reuse of packaging (Franckx, van Acoleyen et al. 2008).

The following example shows how food companies are adopting a service innovation with the aim to green their supply chain and ensure regulatory compliance. This case is a combination of the direct pressures in the adopter sector (Food and Drinks) and the opportunity perceived by a provider sector (KIBS), a sort of indirect effect on the latter. Food companies may perceive regulatory pressure coming from chemical substances (REACH), hazardous materials and regulatory risks, but this may not necessarily motivates them to exert it in product innovation.

Marketing and service innovations

Service innovation might be the preferred option. In the case below it is noticeable that the Norwegian firm in the KIBS is combining in-house knowledge in combination with highly sophisticated technology coming from the EOE sector. This combination enables them to deliver traceability services for greening the value chain of food companies, at the time the latter firm can show to their consumers that their products are ethically produced and in an environmentally conscious way. On a very interesting note, a subsidiary company was created by a large Danish food company in combination with a global ICT/KIBS firm. The nutrition division of a German conglomerate followed a similar strategy, and decided to launch an area of KIBS services, and not a spin-off firm. These examples show the role of large corporations in the food value chain and its impact of eco-innovation.

Other manufacturers are already advertising with labels that indicate the share of renewable energy sources being used for production (e.g. “Dagoba”). Sustainable food production looks like a large innovation area for the industry, which especially concerns production methods and concepts for energy usage (renewable energy, energy efficiency and using food waste as energy source).

5.3 Gazelles

A “gazelle” is defined as "a company that experiences an extended period of rapid growth”, which may be mostly associated with ICT companies like Hewlett-Packard that developed from a garage laboratory into a large international industry. Whereas many companies that start small remain small or even vanish, a few manage to exhibit very fast growth rates over a short period of time, which is can also be economically reflected in the phenomenon of small caps exhibiting accelerating growth/returns.

Although there do not appear many examples of recent gazelles in the food and drinks industry, we provide one illustrative example of a gazelle in the food and drinks industry: the UK based drinks company “Innocent Drinks”. “Innocent” specialises in fruit and vegetable smoothies, founded in 1999 by 3 people and now employing around 250 people with a turnover of £100 million in 2009, experiencing exponential growth since 1999. Although the product idea of "Innocent" as such is actually neither particularly innovative (fruit and vegetable smoothies) nor high-tech as they advertise with 'naturalness', their business concept seems to have contributed much to their success. Their innovativeness is their power to combine many dimensions popular with consumers (naturalness, functional drinks (health improvement), being ethical and adhering to environmental and corporate responsibility, running charities, making extensive use of social networking and interactive web presence, being unconventional). It is the company's ability to grasp the trends and wishes of the customer and react to topics like fair trade, 'naturalness', health and ICT interaction and utilise practices like social networking to obtain and maintain customer involvement and binding that seem to make it successful and innovative. The example clearly shows that in the area of foods and drinks, companies can be very successful without utilising high-tech product innovations.

6 Policy analysis and conclusions

As already mentioned before, the principal technological possibilities in the area of food and drinks production are high and even growing. The major challenge, however, lies in bringing these possibilities in line with solving current challenges and fostering the developments towards desirable futures. Although ‘desirable’ may mean different things to different people, some major aspects have been identified as being rather undisputable:

6.1 Healthy nutrition

Making foods and drinks generally more healthier

As it has also been mentioned within the “Food for Life” reports (ETP 2007 and ETP 2005), healthy and of course safe nutrition are key desires for society as well as the industry. This already starts with rather small improvements in common products. The reduction of ingredients considered as harmful to health and wellbeing like trans-fats, cholesterol, too much salt and sugar as well as food ingredients that may heighten the proneness to cancer should stand in the centre of attention and support. There exist two factors that may counter these efforts which are costs and possibly consumer preferences. As food and drinks processing is a very complex process and leaving out some ingredients may significantly affect the end product even in important properties such as shelf life (e.g. in case of salt and sugar) as well as other properties like taste and consistency (e.g. fat), substitutions or reductions require the development of new production methods, recipes and thus innovation which requires investments. Here governments and policy-makers could provide support since healthier nutrition has a preventative effect that also benefits public health and can reduce costs there. As in regard to prices, ways should be found how to make healthy nutrition affordable for all and here also information programmes, training and education in schools could be good starting points.

Evidence-based assessment of functional food possibilities

More and more attention is paid to functional food and the technological possibilities for further developments exist and often come from other domains like biotechnology and medicine. However, some claims about functionality are still more speculation than science and some benefits (e.g. of Ginkgo in regard to mental health) are disputes. Thus efforts in research should also be dedicated to sound and evidence-based assessment of functional ingredients and their real workings, benefits or even dangers for the human body. The health claim regulations for functional foods and drinks and their advertisement already seem to point towards the right direction of evidence-based functional food and drinks. This is also in line with the overarching goal of achieving healthier nutrition.

Also research in natural functional ingredients – ranging from health benefits to preservation methods – seems to get increasing interest also from the consumer side and should get supported since especially many artificial preservatives are considered having negative health effects.

Such assessments should also be conducted in regard to the usage of GMOs or nanotechnologies in food processing by improving risk-benefit analysis.

Improvement of food safety

Improving food safety is another important aspect of healthy nutrition which can be achieved in different ways and needs to be considered throughout the whole food chain from farm to fork. It not only includes aspects like improved conservation methods (especially the development of conservation methods that do not compromise nutritional value and taste) and better and faster testing methods (e.g. based on developments in biotechnology like lab-on-a-chip technologies) and innovations in packaging (smart packaging that constantly measures and displays the real food quality) but also training programmes in hygiene (e.g. Hazard Analysis and Critical Control Points - HACCP) and stricter controls to uncover hygiene problems and frauds.

Promoting healthy eating and healthy cooking

Not only industrial food and drinks processing can be a cause for health issues but also consumer choices and improper food preparation and cooking at home. Schools could be a place where nutritional education, healthy eating as well as cooking could be taught. Such curricula could be supported by policy-makers and ministries. It would also serve two positive purposes: a general improvement of personal and public health (e.g. by preventing food-related diseases such as obesity) as well as encouraging more people to get interested in nutrition-related work areas since many food and drinks companies currently are concerned about a lack of qualified personnel.

6.2 Ecological sustainability

Reducing energy and water consumption

The energy consumption in food and drinks processing is mid-range as compared to other major industries, but especially water consumption and water contamination is high within conventional agriculture and food/drinks processing. Some food and drinks companies are already developing strategies for utilising renewable energy resources in food/drinks production or feeding food waste into the energy cycle. Such ideas should get more support from industries, consultancies, governments, financial institutions and consumers.

As in regard to waste, a potential conflict could occur between convenience and reduction in packaging (fast food), but also here solutions can be found like the usage of bio-degradable packaging or the use of natural packaging materials (e.g. leafs). However the usage of organic packaging materials could come with trade-offs in regard to preservation (difficulty of air-tight packaging by using organic materials) and possibly hygiene. But innovation support in material science and development could also yield more suitable solutions in the future.

6.3 Ethics

Ethical aspects in food consumption are also getting more important to a growing number of consumers and include issues like animal treatment and fair trade. Industrial/factory is considered as cruel for animals and an increasing number of customers are becoming aware of this situation and choose products from alternative methods in cattle farming and animal production. Meat in general is getting under growing criticism from the perspective of health as well as ethics and animal wellbeing, and some innovative ideas for producing meat without the need for whole animals from cultured cells are already under development and get support from animal rights and environmental groups (e.g. PETA).

On the other side, meat consumption is also a matter of culture and habit. Therefore finding solutions for a more sustainable and ethical production should also be supported by policy from the perspective of health and food safety (diseases and the use of growth hormones) as well as environmental sustainability and animal protection (laws in regard to animal protection and slaughter).

Although food security (getting enough food and drinking water) may not be a problem for the EU, there is also a global responsibility and activities in other parts of the world can be related to the European food chain and European activities can affect sustainability in other countries.

6.4 Economy and business

Affordability and quality

The seemingly growing needs for efficiency in food/drinks processing and price reduction of products seem to conflict with the calls for improvements in health, sustainability and safety. Many current practices applying less healthy ingredients or factory farming, for example, are said to be done due to price competition. Thus, price policies as well as issues of overproduction and food waste may also be reflected upon. Finding solutions for affordable quality and healthy choices seem to be an important issue.

Innovation for SMEs

The food and drinks manufacturing industry is dominated by micro-enterprises with less than 10 employees that make up 78.6% of all firms. In contrast SMEs and even micro-companies in niche areas of new technologies that may be able to generate innovative goods and services, it may be more difficult for food and drinks SMEs to innovate due to limited financial and human resources and higher labour intensity. Thus ways may be considered to better support food and drinks SMEs to improve their products and obtain necessary know-how.

Clusters and interdisciplinary cooperation

As it has been outlined within this report, the necessity of interdisciplinarity, e.g. between biotechnology, medicine, life sciences, material sciences, ICT and food and drinks production (through the whole food chain) is getting increasingly important for improving parameters like healthy nutrition, safety and sustainability. Life sciences and biotechnology, for example, can help with improved testing as well as evidence-based assessment of health claims, functional food and healthy eating in general (e.g. based on findings of nutrigenomics and metabolomics). Material sciences and ICT can improve packaging, shelf life and safety (e.g. through smart labels) as well as providing technologies for tracking, tracing and assessing ecological footprints (e.g. through RFID tagging). But also societal, behavioural and psychological studies are of value for analysing eating habits and consumer reactions towards products and marketing. Thus, the embedding of food and drinks companies into multidisciplinary clusters could provide fruitful inputs for the generation of innovations.

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Annex – Overview of SIW deliverables

Overview of the deliverables from the Europe INNOVA Sectoral Innovation Watch

Deliverables can be downloaded from www.europe-innova.eu

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Task 5 Input and Output Papers

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