Innovations at the Borderline of Food, Nutrition and Health in Germany

A Systems' Theory Approach

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Summary

This article deals with the innovation system in Germany at the borderline of food, nutrition and health. After an overview over existing concepts to analyse innovations in system theory, the major factors (technologies, economic competence, institutional infrastructure, development block) are studied which determine the innovation system in this area in Germany. Afterwards recommendations are outlined on how to modify the innovation system in future.

Key words: Food; Nutrition; Health; Food industry; Functional Food; Innovation system; Technological System; Germany

Zusammenfassung

Dieser Beitrag beschäftigt sich mit der Ausgestaltung des Innovationssystems an der Schnittstelle von Lebensmitteln, Ernährung und Gesundheit in Deutschland. Zunächst wird ein Überblick über bestehende systemtheoretische Ansätze zur Analyse von Innovationen gegeben. Anschließend werden die wichtigsten Faktoren untersucht, die das Innovationssystem in diesem Feld in Deutschland bestimmen (z.B. Technologien, wirtschaftliche Kompetenz, institutionelle Rahmenbedingungen, Development Block). Zum Abschluss werden Empfehlungen zur Anpassung des Innovationssystems an die zukünftigen Herausforderungen erarbeitet.

Schlüsselwörter Lebensmittel; Ernährung; Gesundheit; Ernährungsgewerbe; Functional Food; Innovationssystem; Deutschland

1 Introduction

In recent years the food market in Germany is characterised by increasing individualisation of consumption patterns. In this context, both price and quality arguments get growing relevance. Socio-demographic developments (like e.g. increasing employment of women) support the demand of convenience food (MEFFERT et al., 2000). In addition, health-related arguments influence the consumption of food to a higher extent, not in the least due to the BSE crisis and several food scandals. In this context the consumption of "health-oriented" food products (like e.g. Functional Food, dietary food supplements) and food produced by ecological farming is growing in most EU countries as well as in Germany (MICHELSEN et al., 1999). These basic trends which most probably will continue in the coming years put pressure on the food industry to develop innovative products (and services). But most of the small and medium-sized companies of the food industry in Germany have very limited capacities and knowledge to adopt new scientific and technical developments which currently take place in food technology and nutritional science. Therefore it is the target of this article to analyse the innovation system at the borderline of food, nutrition and health in Germany and give recommendations how to improve the system in order to manage the challenges in the coming years.

2 System theory approaches for the analysis of innovation activities

Innovation activities of companies are typical examples for complex processes with a long-term perspective which are characterised by multiple feedback-loops and interactions with a great number of actors located within and outside the companies (EDQUIST, 1997, pp. 1 – 35). Therefore innovation activities represent an ideal area to use system theory approaches for the analysis of such processes. Since the 1980s a series of different approaches and empirical studies can be registered which are rooted in the works of SCHUMPETER. In this context two basic concepts have been developed to analyse processes of technological change and innovations within an economy:

- National systems of innovation (NSI)
- Technological systems (TS)

Other "systems approaches" have been suggested in economics literature which mainly focus on the competitive relationships among enterprises (CARLSSON, 1997, pp. 1.22). In this context MICHAEL PORTER's "diamond" described in his 1990 book "The competitive advantage of nations" represents an important contribution focussing essentially on clusters of industries. The four sides of the diamond are made up by factor conditions (e.g. skills, technologies, capital), demand conditions, links to related and supporting industries, and the company strategies, structure and rivalry. Within this context PORTER regards each economic activity as part of a cluster of agents and activities rather than taking place in isolation. TRAILL and PITTS (1998) describe in detail the use of PORTER's "diamond" in the food industry. A similar focus like PORTER's "diamond" is represented by "sectoral innovation systems" (BRESCHI and MALERBA, 1995; MALERBA and ORSENIGO, 1993, pp. 45 – 71). This approach is based on the idea that different industries operate under different technological regimes which are characterised by specific combinations of opportunity and appropriability conditions, degrees of cumulativeness of technological knowledge, and specific ways of knowledge generation. The concept of "local industry systems" as 1994 represented by ANNA LEE SAXENIAN's study of the electronics industry in Silicon Valley in California and along Route 128 in Massachusetts focusses on differences in culture and competition among the two regions. This led to differences in the degree of hierarchy and concentration, experimentation, collaboration and collective learning which have entailed differences in the capacity to adjust to changing market developments (SAXENIAN, 1994).

2.1 National systems of innovation

The notion of "National Systems of Innovation" (NSI) was introduced by LUNDVALL in 1988 (FREEMAN, 1995, pp. 5 –

24). The basic idea of this approach refers to FRIEDRICH LIST who wrote his publication "The national system of political economy" in 1841 (LIST, 1841). In the late 1980s, FREEMAN (1988, pp. 331 – 348), LUNDVALL (1988, pp. 349 – 369 and 1992a), and NELSON (1993) launched a series of studies on national innovation systems.

The NSI approach cannot be regarded as a formal theory, rather it provides a conceptual framework for analysing the specific factors influencing the innovative capabilities of companies (EDQUIST, 1997, pp. 1 – 35). The NSI approach assumes that the innovative capabilities of a firm depend on its ability to communicate and interact with a variety of external sources of knowledge (e.g. other firms, suppliers, users, scientific institutes, service and supporting institutions) as well as on the ability to co-ordinate a variety of interdependent sources of knowledge within the firm itself (e.g. R&D, production, marketing/sales) (FREEMAN and SOETE, 1997).

The NSI approach rests on four basic concepts: innovation, learning, system and nation. "Innovation" refers to the activities of companies to develop, introduce and diffuse new products and production processes (NELSON and ROSENBERG, 1993, pp. 3 – 22). These processes depend on "learning" from a variety of activities undertaken within companies, on the co-ordination of this internal knowledge as well as its integration with knowledge acquired from external sources. According to LUNDVALL (1992, pp. 1 – 22) learning is regarded as a complex process which involves new knowledge as well as new combinations of existing knowledge. Learning processes draw upon a variety of sources of knowledge and are carried out in a multiplicity of activities in society. In this sense processes of organisational and institutional change and learning are also included in the NSI approach.

Because innovation involves different forms of interactive learning, LUNDVALL suggests to address it within a "systems approach" (LUNDVALL, 1992, pp. 1 – 22), which is common to all authors dealing with the NSI approach (EDQUIST, 1997, pp. 1 – 35). In general terms, a "systems approach" assumes that the overall performance of a complex of elements depends not only on the characteristics of the single elements, but on how these elements mutually constrain and influence each other. Therefore, it is not sufficient to specify individual elements or constituent parts of the system, but to emphasise the interdependent relationship between these elements (EDQUIST, 1997, pp. 1 – 35)

The fourth basic concept of the NSI approach represents a "nation state" which is defined by the boundaries, not only in geographic terms, but also for relatively homogenous patterns of social and cultural values shaping the institutional set up of a system of innovation (LUNDVALL, 1992, pp. 1 – 22) and by the role of the state and its public policy (EDQUIST, 1997, pp. 1 – 35). Because of differences in public policies, significant differences across nations emerge in a variety of factors in a NSI, like e.g. regulation and standards, formal education system, property rights, shaping of the financial and banking system, communication infrastructure (JOHNSON, 1992, pp. 23 – 44). However, globalisation and regionalisation may lower the relevance of national boundaries for National Systems of Innovation.

Many authors have contributed to define the elements of the NSI and although there are overlaps in their views, the overall framework is conceptually ambiguous since the definitions of the elements of NSI basically fall into two categories. The "narrow" definition concentrates on the institutional actors involved in producing and diffusing new knowledge and technologies. The focus of this definition is on innovation as the outcome of processes of learning-by-searching of private institutions and learning-by-exploring by public institutions. Therefore NELSON and ROSENBERG (1993, pp. 3 – 22) stress that the basic dimensions which need to be explored in empirical studies on NSI are: (i) the allocation of R&D activities and the sources of its funding, (ii) the characteristics of firms and the important industries, (iii) the role of universities and (iv) government policies expressly aimed to support and regulate industrial innovation. In the "broad" approach, a NSI encompasses all institutions and structural factors which affect the introduction and diffusion of new products, processes and systems in a national economy (FREEMAN, 1992, pp. 169 – 190). Such institutions are wide-ranging and include the production system and all inter-industry linkages, the marketing system, the users of innovations (companies, government), labour markets, the finance and regulatory system as well as trade policy (LUNDVALL, 1992, pp. 1 – 22).

2.2 Technological systems

In contrast to an innovation system, the concept of Technological systems (TS) focuses more on the technology itself and its mediation. The concept of TS seems to have first been used by THOMAS HUGHES 1983 in his study on the electrification of the US railway company Western Society during the period 1880 – 1930 (CARLSSON and STANKIEWICZ, 1995, pp. 21 – 56). Afterwards there have been several studies on the development of electric power, railroad, telephone, and air traffic systems in Europe and the USA (BIJKER et al., 1987, MAYNTZ and HUGHES, 1988) using sometimes slightly modified variations of this approach without developing a theoretical framework.

Technological systems have been defined as a "network of agents interacting in the economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion and utilisation of technology" (CARLSSON and STANKIEWICZ, 1995, pp. 21 – 56). They are based on the dynamic concept of "development blocks" which was introduced by DAHMÉN in the 1950s (DAHMÉN, 1989, pp. 109 – 122). TS are characterised by knowledge or competence flows rather than the flows of ordinary goods and services, i.e. in this sense TS represent dynamic knowledge and competence networks.

In the presence of an entrepreneur and sufficient critical mass, such knowledge and competence networks may be transformed into innovative "development blocks", i.e. synergistic clusters of companies and technologies within an industry or a group of industries (CARLSSON and STANKIEWICZ, 1995, pp. 21 – 56). "At the core of a development block is a basic technology which may be referred to as a technological paradigm[1]). In complex development blocks, the core may be a cluster of technologies, each of

1) Technological paradigms define the technological opportunities for further innovations and some basic procedures on how to exploit them. Thus they also channel the efforts of the agents in certain directions than in others (Dosi, 1988).

which follows a particular trajectory"[2]) (CARLSSON and STANKIEWICZ, 1995, pp. 21 – 56).

For the transformation of a knowledge and information network into a development block, the presence of substantial entrepreneurial activity play an essential role. It is not only the task of entrepreneurs to respond to market signals by searching and investing in new technical solutions, but also to create new markets (CARLSSON and STANKIEWICZ, 1995, pp. 21 – 56). The aptitude of a single entrepreneur or a firm to explore new markets depends on their economic competence, i.e. how they use their knowledge and available information (CARLSSON and STANKIEWICZ, 1995, pp. 21 – 56) to "identify, exploit and expand business opportunities" (CARLSSON and ELIASSON, 1994, pp. 687 – 711). These abilities coincide with the "core competences of the corporation" discussed by PRAHALAD and HAMEL (1990, pp. 79 – 91). Thereafter, a company has to define one or more core competences as a foundation for future prosperity, which the company's growth will be based on (e.g. expertise in a certain technology or marketing strategy). PRAHALAD and HAMEL (1990, pp. 79 – 91) identify four characteristics, saying that a core competence

- "...provides potential access to a wide variety of markets...",
- "...should make significant contribution to perceived customer benefits of the end products...",
- "...should be difficult for competitors to imitate...",
- "...is enhanced as it is applied rather than diminished with use...".

Another prerequisite to transform knowledge and competence networks into a development block is the need of a critical mass which is directly linked to the nature of innovation. DOSI (1988, pp. 221 – 238) listed five "stylised facts" about innovation and described them with attributes such as uncertainty, science base, complexity, experimentation (learning process) and cumulative character. Hence, the efforts of a few innovators might be "too meagre to stimulate economic development" (CARLSSON and STANKIEWICZ, 1995, pp. 21 – 56) thus requiring the interaction among agents with different competences. This might apply technologically and geographically especially in high technology fields. The increasing importance of the factors as described in DOSI (1988, pp. 221 – 238) gives reason for knowledge and competence networks. By combining ("linking") the competences of each member of the network and their collaboration, it is intended that each "node" performs better compared to a single unit. This particularly concerns the exchange of complex information (IMAI, 1989, pp. 123 – 156). In a TS formal and informal networks are combined and can be regarded as mediating structures between the knowledge base of a sector and the companies active in it. Their quality influences the degree to which the firms can exploit the emerging technical opportunities (CARLSSON, 1997, pp. 1 – 22). Hence, the importance of TS increases with the complexity and heterogeneity of the knowledge base of innovations.

The development of a TS as well as the transformation of a knowledge and competence network into a development block depends on the institutional infrastructure as well. CARLSSON and STANKIEWICZ 1995 define the institutional infrastructure of a TS as "a set of institutional arrangements .... which, directly or indirectly, support, stimulate and regulate the process of innovation and diffusion of technology" (CARLSSON and STANKIEWICZ, 1995, pp. 21 – 56). In this context they refer to organisations and regimes affecting the political system, educational system (including production and distribution of knowledge), labour regulations and the treatment of intellectual property rights. The institutional infrastructure might change over time, possibly resulting in a "loss of dynamic efficiency", thus hindering innovation and technical change instead of supporting it. In addition, "the effective organisation of production and distribution of knowledge and competence is by far the most intricate institutional issue related to the promotion of technological change" (CARLSSON and STANKIEWICZ, 1995, pp. 21 – 56).

3 Innovation system at the borderline of food, nutrition and health

Around one third of the costs of the health care system in Germany are caused by diseases which are directly or indirectly influenced by nutritional factors (KOHLMEIER et al., 1993). In this context coronary heart diseases, some forms of cancer (e.g. colon, stomach, pancreas, liver, breast cancer), diabetes, osteoporosis and some chronic auto-immune diseases play a prominent role (HÜSING et al., 1999). Given this background sound knowledge about the causal relationships between food, nutrition and health or well-being of the consumers are of high political interest. Furthermore, such knowledge forms the basis for producing innovative food products by the industry as well as improving the recommendations for optimising the nutritional behaviour of the population in a country.

Therefore the innovation system at the borderline of food, nutrition and health in Germany is analysed in the following using the TS approach because significant changes in nutritional science and food technology support such a procedure. Empirical data of different sources (e.g. official statistics, data from market research institutions, company information, expert interviews which have been carried out by our institute in the context of two technology assessment studies on Functional Food (MENRAD et al., 2000a, HÜSING et al., 1999) will be used for this purpose. Because of the multidisciplinary character and the infant status of this innovation system, the (quantitative) empirical basis for Germany is limited so far. However, a first picture of the current situation as well as main influential factors for future developments can be provided. Therefore the technologies, the economic competence, the institutional infrastructure as well as chances that the existing system may transfer to a "development block" at the borderline of food, nutrition and health are analysed in the following.

3.1 Technologies

The demand of consumers for health-oriented, minimally processed food with a high convenience character represents new challenges for the production and processing of food. In recent years new technical approaches of food processing and food packaging have been developed targeted to a mild and minimally processing of food in order

2) A technological trajectory is the activity of technological progress along the economic and technological trade-offs defined by a technological paradigm (DOSI, 1988).

to preserve its nutrition-related ingredients and if possible enhance quality of the product. Examples of such technologies are Ultra High Temperature (UHT) Sterilisation, High Pressure, Sous-vide method, Modified Atmosphere Packaging (MAP) and aseptic packaging of food (MENRAD et al., 2000b). Some of these technologies are already practically used in the food industry to a certain extent (e.g. Ultra High Temperature (UHT) Sterilisation, Modified Atmosphere Packaging (MAP)) while others are still in the optimisation phase (e.g. High Pressure, Pulsed Electric Fields, Light Pulses).

One specific segment of health-related food products are Functional Food (figure 1). Although there are different definitions for Functional Food all authors agree that Functional Food are processed food which should not only feed consumers but offer additional benefits related to the preservation and improvement of physical and mental well-being as well as reducing the risk of falling ill with nutrition-related diseases (MENRAD et al., 2000a). Functional Food contains specific ingredients, which have an effect on the metabolic functions growth, development and differentiation, metabolism of macro nutrients, preservation of bone health/prevention of osteoporosis, resistance to reactive oxidative species, cardiovascular system, physiology of the gastrointestinal tract as well as behaviour, mental and physical fitness. Currently, important functional ingredients are pro–, pre– and synbiotics, antioxidants**,** secondary plant metabolites, structured lipids, polyunsaturated fatty acids, fat replacers and substitutes, bioactive peptides, fibres, vitamins and minerals. At present, Functional Food products are mainly developed to prevent cardiovascular diseases and osteoporosis as well as to influence gastrointestinal health (MENRAD et al., 2000a, HÜSING et al., 1999).

A wide range of traditional and new technologies can be used for R&D processes and the production of Functional Food which range from traditional technologies (like e.g. fermentation and enzymatic processes) to newly developed approaches (such as e.g. High Throughput Screening, micro capsules) which are partly used in the pharmaceutical industry as well. In this context it has to be emphasised that genetic engineering represents one technology which can be used to develop Functional Food in very specific fields (e.g. for the development of probiotic *lactobacillus*-strains) but none of these products has been commercialised so far.

At the same time a change of paradigm emerges in nutrition-related research. While in recent years nutrition-related research was very much oriented towards the specific macro and micro nutrients of food (and raw materials) as well as technological aspects, a new field of interest emerges in nutrition-related research in which the effects of food components on specific metabolic functions are analysed functionally in order to use this knowledge to optimise the quality characteristics of food (MENRAD et al., 2000b). In this context additional impulses are expected from the finishing of the sequencing of the human genome (International Human Genome Sequencing Consortium, 2001, pp. 860 – 921)**.** In addition to methodological progresses (e.g. the development of DNA micro-arrays) it is expected that in particular the movement to "functional" genomics which is foreseen for Human Genome Research in Germany in the coming years (BMBF, 2001a) will contribute significantly to the knowledge related to the emergence and development of nutrition-related diseases. In this sense nutritional science is moving closer to medical and pharmaceutical research and incorporates scientific methods and approaches used in disciplines like biochemistry, molecular biology, medicine and food technology.

3.2 Economic competence

CARLSSON and ELIASSON (1994) defined economic competence as the ability "to identify, expand and exploit business opportunities". In the field of innovative, health-related food products there are two main aspects of economic competence, namely the *buyer competence* (i.e. the existence of a sufficiently large number of buyers and/or users of such products) and the *supplier competence* which refers to the existence of a sufficiently large number of food industry companies which are able and willing to offer health-related food products as well as the suppliers of "functional ingredients".

Buyer competence

Health aspects are gaining increasing relevance in food consumption and nutrition in Germany. In consumer surveys health-related aspects are regarded as getting more important by consumers in recent years. In addition, recent crises in the Agro-Food sector (e.g. BSE crisis, outbreak of Mouth and Foot disease) highlight the high relevance of nutrition and health aspects as well as the increasing awareness of consumers in more actively managing their diets. Another important driving factor in direction of health-related nutrition is the increasing relevance of elderly people in the coming years. According to available prognoses the percentage of people older than 65 years will double within the coming 40 years reaching then around one third of the population in Germany (MEHLER, 1998, pp. 10 – 12).

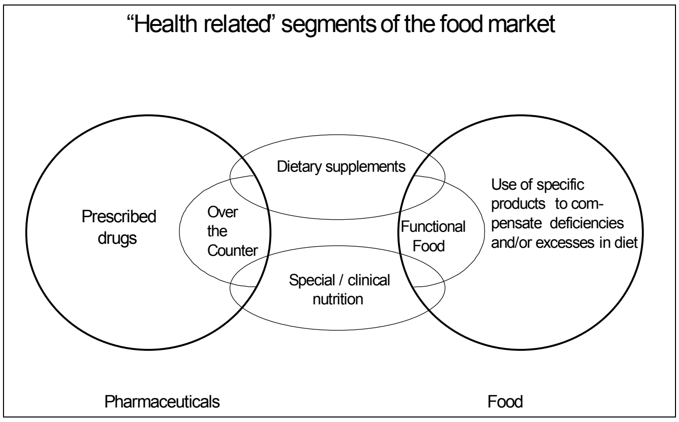


Figure 1

These general socio-economic tendencies will influence different segments of the pharmaceutical and food market in Germany (figure 1). This relates in particular to Functional Food, dietary supplements, nutrition for specific purposes (including clinical nutrition) as well as the consumption of specific food products in order to compensate deficiencies and/or excesses in the diet. Examples for the latter area which cannot be clearly defined are the use of low-fat or light products in order to compensate a too high consumption of fat or sugar or the use of fortified products in order to compensate deficiencies in other parts of the diet. Another segment of the food market which is influenced by the change to a healthier lifestyle are organic food products since health aspects are gaining increasing relevance as buying motive for these products (IMKAMP, 2000, pp. 193 – 202).

In 2000 the "Over the Counter Market" (OTC) market with pharmaceuticals (which can be sold without prescription of a medical doctor) achieved a market volume of around 14 billion DM in Germany (WALLUF-BLUME, 2001). Pharmaceuticals which do not have to be sold in pharmacies amount to around 1.68 billion DM (HEIMIG, 2001, pp. 39 – 40). Although most of these products are sold in pharmacies and specific drugstores, pharmaceutical products valued around 237 million DM have been sold in food retail stores in Germany in 2000 as well.

Some of these free-for-sale pharmaceuticals are included in the market segment of "dietary supplements" as well. In total, "dietary supplement" products worth more than 1.5 billion DM are sold in drugstores and food retail shops in Germany in 2000 (HEIMIG, 2001, pp. 39 – 40). Within this market vitamins and minerals are the most important segments valued around 270 million DM. Between 1999 and 2000 in particular products targeted to stomach and gut health as well as coughs and colds have increased their market volume significantly (HEIMIG, 2001, pp. 39 – 40). There is only very limited information available concerning the market volume and development of clinical nutrition in Germany not least because this type of food is hardly sold in general retail stores but mostly used in specific health institutions (like hospitals or rehabilitation centres).

One specific segment of the food market which is directly targeted to health aspects is Functional Food. Due to the differing definitions, there are widely varying estimations related to market volume and market growth of Functional Food. Taking into account a definition which includes fortification of food with functional ingredients which are assumed to have a positive impact on consumers' health and this information is transferred to the consumer, the global market of Functional Food is estimated up to 63 billion DM (LEATHERHEAD, 2000). The most important market with the highest growth perspective represents USA with around 50 % of the global market, followed by Japan with a market volume of 7.5 billion DM (SEHAT et al., 1999, pp. 723–741).

In Europe the market of Functional Food exceeds the volume of 4 billion DM of which Germany count for more than 800 million DM followed by France and the United Kingdom. This means that in Europe as well as Germany the current market share of Functional Food is still below 1 % of the total food and drinks market. Around two thirds of the Functional Food market in Europe as well as in Germany are represented by "functional" milk products (like e.g. probiotic and prebiotic yoghurt, probiotic milk drinks). This product group has shown an impressive growth during recent five years bringing the market volume in Germany from around 10 million DM in 1995 to 519 million DM in food retail stores (without Aldi) in 1999 (MENRAD, 2000, pp. 295 – 302, HILLIAM, 2000a, pp. 12 – 14). This equals to around 20 % of the yoghurt market in Germany. Another important product category within the Functional Food segment are non-alcoholic beverages fortified with the vitamins A, C and E. In 1999 these beverages reached a market volume of 178 million DM up from sales of around 119 Mill DM in 1998 (HILLIAM, 2000b, pp. 17 – 19). In 2000 more than 117 mill. liter of vitaminised non-alcoholic beverages have been consumed in Germany (VON PILAR, 2001, pp. 40 – 44) which equals to around 1 % of the total consumption of these beverages. Other relevant segments of the Functional Food market in Germany represent chewing gums for dental hygiene as well as rather singular products in bakery and breakfast cereals, candies, spreads and infant food. Despite the observed market growth, the market introduction of Functional Food is characterised by a significant share of product failures which is typical for the highly competitive food market in Europe. Although it is expected that Functional Food will double their market volume within the coming five years, they will not loose their niche character within this time period in Europe (MENRAD et al., 2000a).

Supplier Competence

When analysing the supply structure of Functional Food, the difficulty emerges that the Functional Food "industry" is almost as fragmented and difficult to define as the market. Taking into account these difficulties, six main types of actors in the commercial Functional Food segment can be identified in the EU and in the German market:

- Multinational food companies with a broad product range
- Pharmaceutical and/or dietary products producing companies
- National "category leaders"
- Small and medium-sized companies (SMEs) of the food industry
- Retail companies
- Supplier of "functional ingredients"

Since the mid 90s several multinational food companies (like e.g. Nestlé, Danone, Unilever, Kellogg, Quaker Oats) have introduced Functional Food products into the EU and German market. This relates in particular to the market of functional milk products which was initiated by the market introduction of Nestlé's LC1 yoghurt in 1995 followed by the Actimel-line of Danone. One major impetus for the marketing of functional milk products by European food companies was the market introduction of one of the leading Japanese probiotic milk products named "Yakult" in 1994 in the European market (MENRAD, 2000, pp. 295 – 302). These three companies still have a leading position in the functional dairy market in Europe. Another example represents Unilever which has introduced a specific functional variety of Becel-margarine (named "Becel proactiv") in the EU in 2000. This margarine is supposed to lower the cholesterol level in the blood.

These multinational food companies with established and well-known brands have the resources necessary for product development and marketing of Functional Food. While in general the total costs from the product idea to market introduction of new food products are estimated to several million DM (WEINDLMAIER, 2000), the development and marketing costs of Functional Food products may exceed this level by far. According to expert estimations the costs for product development and market introduction of Nestlé's LC1 yoghurt and the Becel proactiv margarine of Unilever exceeded 100 million DM each. Most of the multinational food companies offering Functional Food products have their own R&D departments and specific in-house resources and expertise in nutritional and food technology research. Some of these companies spend up to 2 % of their turnover for R&D activities (WEINDLMAIER, 2000). In addition to product development the proof of efficacy of Functional Food products in clinical studies requires some time (several months up to more than one year) and relatively high financial investments. Pioneering companies have to support the market introduction of Functional Food with intensive PR and information campaigns. In addition, general success factors for the marketing of food (like e.g. taste, convenience, packaging, perceived "value" of the product) are valid for Functional Food as well (HÜBEL et al., 2001, p. 8).

A second type of Functional Food producers represent pharmaceutical or dietary products producing companies like e.g. Novartis Consumer Health, SmithKline Beecham, Johnson & Johnson or Abbott Laboratories. In particular, Novartis Consumer Health has launched a series of Functional Food products including biscuits, cereal, cereal bars and beverages in different European countries under the "AVIVA" brand in 1999. One important motivation for pharmaceutical companies to invest in Functional Food are the shorter development times and lower product development costs compared to pharmaceutical products (MENRAD, 2000, pp. 295 – 302). In addition, pharmaceutical companies have intensive experience in organising clinical trials to substantiate health claims of a specific product.

A third group of Functional Food producers are companies specialised in a particular product category which mostly belong to the market leaders on a national level. Examples for this type of companies represent Molkerei Alois Müller (with its functional "ProCult" dairy products), Ehrmann ("DailyFit" dairy products), Bauer (with several probiotic dairy products), Eckes (ACE drinks) or Becker Fruchtsäfte (ACE fruit juice) in Germany. In most countries of the EU as well as in Switzerland, in particular in the dairy industry the leading companies on a national level are often among the producers of pro- or prebiotic dairy products (FROST & SULLIVAN, 2000, MENRAD et al., 2000a).

There is a limited number of small and medium-sized food companies (SMEs) active in the Functional Food market as well. These companies mostly produce functional products for market niches or offer me-too products following the pioneering products of the multinational companies. Often these products can "survive" only for a rather short time period (e.g. up to two years). In general, SMEs lack the know-how and resources for own intensive R&D activities and cannot afford to spend high sums in specific information or advertising activities necessary to open a specific segment of the Functional Food market as pioneering company. The same relates to long-lasting clinical trials (e.g. intervention studies with high number of patients) which may be necessary to show efficacy of a specific "functional ingredient" (MENRAD et al., 2000a).

Food retail companies are increasingly starting to introduce retail brands especially in the relatively "mature" markets of functional milk products. In Germany this relates in particular to food discounters like Aldi, Lidl and Penny who launched pro- and prebiotic dairy products in recent years. It is estimated that Aldi who launched its probiotic dairy brand "Bi'AC" in 1997 will generate around 180 million DM turnover with probiotic dairy products (which is not included in the above mentioned turnover of functional dairy products since this figure is restricted to the food retail companies without Aldi; Anonymous, 2000, pp. 9 – 11). In other European countries food retail brands play a certain role in the functional dairy segment as well (MENRAD et al., 2000a).

Like in the food industry in general, suppliers of food ingredients play a significant role as innovation source in the Functional Food segment as well. Nearly all main food ingredient producers have introduced "functional ingredients" or tried to acquire companies specialised in this field in recent years. This relates e.g. to the world-wide most important producers of vitamins (e.g. Roche Vitamins, BASF) which introduced specific "bioactive" ingredients in the market. Other examples are companies like SKW Trostberg (now merged with Degussa AG), DSM or Eridania Beghin-Say which have created specific business units for functional ingredients. An important role on the market of prebiotic ingredients play subsidiaries of major European sugar producers (like e.g. the Südzucker subsidiary Orafti). In addition, a relatively high number of small or specialised producers are offering functional ingredients as well (e.g. in the probiotic field). So far only a limited number of biotechnology companies has specialised on this field despite the expected growth perspectives (MENRAD, 2000, pp. 295 – 302). In general, the suppliers of functional ingredients try to prove efficacy of a specific substance and sell it to a wide range of food industry companies thereby creating specific formulations. In this sense innovative suppliers of food ingredients are of high relevance in particular for product innovations of SME food companies.

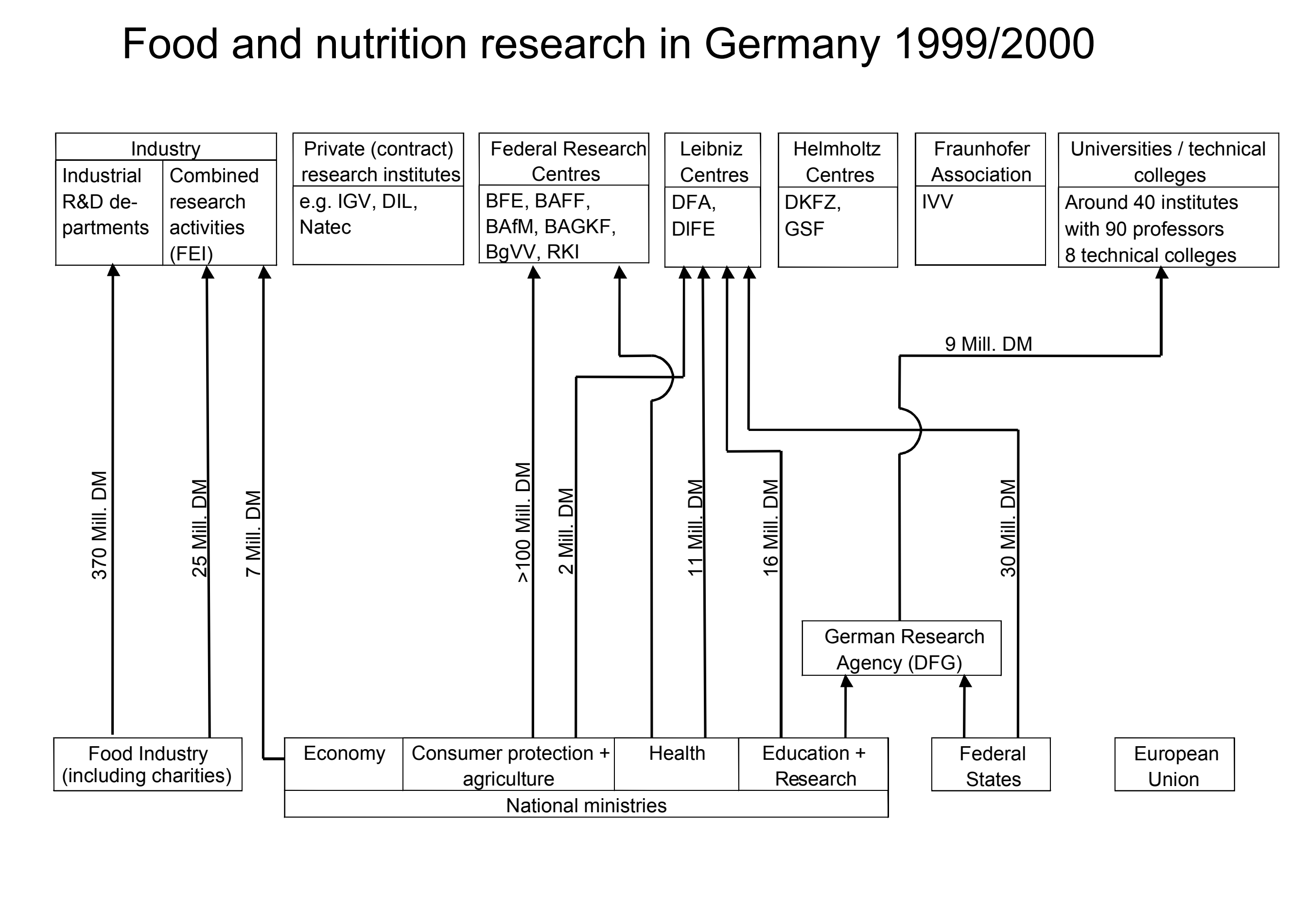
3.3 Institutional infrastructure

In the TS approach the following main components of the institutional infrastructure are highlighted: the organisation of industrial research and development (R&D), academic infrastructure, and government policy.

Industrial R&D activities

In Germany, food and nutrition-related research is carried out in a variety of institutions with private and public ownership. Traditionally the food industry is regarded as a sector with low R&D intensity. In contrast to other industrial sectors the food industry decreased their total investments in R&D activities in recent years. In 1995 around 475 million DM have been spent by food industry companies in Germany for this purpose (BMBF, 2000). These investments decreased to 420 million DM in 1999 most of which has been spent in the own R&D departments of the companies (figure 2). This equals to around 0.6 % of the R&D investments of all industrial companies in Germany in 1999 compared to a proportion of the food industry of around 9.7 % related to the turnover and 8.6 % related to the employees. The R&D intensity (i. e. proportion of R&D expenditures of the turnover) reaches 0.5 % in 1999 in the food industry in Germany compared to an average of 4.0 % in all industrial sectors (BMBF, 2000).

In addition to the industrial R&D activities, food and nutrition-related research is carried out in some privately-owned research institutions as well (figure 2). Often these institutions concentrate their activities on a specific area of



Source: BMBF(2000). – FEI (2000). – DFG (2000a; 2000b; 2001).

Figure 2

the food industry or defined services in food analytics. Given the small and medium-sized character of most of the food industry companies in Germany, the non-profit Research Association of the German Food Industry (FEI) was initiated 1953 in which around 50 industrial companies, 50 professional organisations and around 110 scientific institutions or persons are members (FEI, 2000). The aim of this association is to realise application-related, co-operative research projects between industry and academia. Thus the majority of its total funds (around 25 million DM in 2000) are provided by industrial companies (figure 2).

Public R&D activities

Public institutions play a significant role as scientific base for the food industry in Germany. In addition, they provide “independent” knowledge in food technology and nutritional science. Like in other scientific areas a great variety of different institutions are active in the food and nutrition field although there are relatively limited funds available in this area. Based on a long tradition the German Ministry of Consumer protection, nutrition and agriculture (BMVEL) runs a series of Federal research centres in the agricultural and nutritional field. Direct relevance for the latter have the Federal Research Centres for nutrition (BfE), meat research (BAFF), milk products (BafM) and cereals, potato and lipid research (BAGKF). These four research centres have round 580 full-time personnel of which 144 are scientists. In total the BMVEL spends more than 100 million DM per year for food and nutrition-related research (BMBF, 2000). In addition, food related research activities are carried out by the Robert-Koch-Institut (RKI) and the Federal Institute for health-related consumer protection and veterinary medicine (BgVV) which are administered by the German Ministry of Health (figure 2).

Additional research institutions with relevance for the food and nutrition field belong to the Leibniz Centres (e.g. German Research Institute for Food Chemistry (DFA), German Institute for Nutrition research (DIfE)), Helmholtz Centres (e.g. German Cancer Research Centre (DKFZ), Research Centre for Environment and Health (GSF)), and the Fraunhofer Association for applied research (e.g. Institute for food processing and packaging (IVV)). In addition, around 40 university institutes with more than 90 professors as well as 8 technical colleges are active in food and nutrition research in Germany. However, based on the screening of funded projects and specific programmes in the years 1999 and 2000, it is estimated that the major financing institution for scientific research in Germany, the German Research Agency (DFG) spends only around 9 million DM per annum in food and nutrition-related research (figure 2). Another financial source for German scientists represents the European Union, which finances the Key Action “Food, Nutrition and Health” within the Fifth Framework Programme with 546 million DM (EU, 2000).

Although there is a wide range of different institutions which are active in food and nutrition research in Germany, only part of them carry out research projects at the borderline between food, nutrition and health. Mainly due to the multidisciplinary character of such projects as well as gaps in the information base, it is hardly feasible to estimate the financial volume devoted annually to such activities in Germany. However, by screening the projects of major research funding organisations an indication can be got of the relative importance of such projects**.** Since 1995 the German Ministry of Education and Research (BMBF) funded projects of around 46.9 million DM in the field of food technology and nutrition of which projects funded with around 5.3 million DM (11.3 %) deal with health aspects (BMBF, 2001b). In 1999 the DFG, which is the main research funding organisation for universities, spend around 9 million DM in food and nutrition research (figure 2). However, within the "structural research programmes" of the DFG (like e.g. "Sonderforschungsbereiche", "Graduiertenkollegs", "Innovationskollegs") no project is focussed on the area food, nutrition and health (DFG, 2000a). Five single research projects of universities with estimated costs of around 750 000 DM are targeted to this field (DFG, 2001), what equals to a share of around 8 %.

Table 1: **Participation of institution from Germany in different areas in EU-projects from 1995 to 2000**

Area	Number of projects	Participants from Germany	Projects (in %)
Food	1,017	395	38.8
Agriculture	1,696	779	45.9
Medicine/Health	1,302	583	44.8
Life Sciences	678	370	54.6
Food/Nutrition/Health	128	58	45.0
All projects [1]	2,888	1,326	45.9

1) There are overlaps between the different areas.

Source: Own investigations based on EU (2001).

Additional information concerning the relative position of Germany can be obtained by screening the funded research projects of international organisations. Therefore, the research projects within the Fourth and Fifth Framework Programme of the EU have been analysed for the years since 1995. As shown in table 1 the participation of research institutions located in Germany range from around 39 % of all funded projects in the food area to almost 55 % in the Life Sciences field. Since 1995, in total 128 research projects at the borderline of food, nutrition and health have been identified on EU level which have been funded with almost 255 million DM (table 2). This represents around 4.4 % of all projects funded in surrounding fields. In 58 of these projects (45 %) institutions of Germany have been involved. This indicates that Germany has no specific strength in this area, rather an average position. An in-depth analysis of the funded projects qualifies this estimation: only 10 projects with a total financial volume of 21.6 million DM have been co-ordinated by institutions located in Germany (table 2). This equals to around 7.8 % of all projects and 8.6 % of the funds spent for projects dealing with issues at the borderline between food, nutrition and health. Compared to other countries (e.g. United Kingdom, the Netherlands, Ireland, Belgium) this represents an underproportional participation of German scientists in co-ordinating positions in this field.

In addition to a limited quantity of research activities there are structural deficits in the science base at the borderline of food, nutrition and health in Germany (BMBF, 2001a, DFG, 1999, HÜSING et al., 1999).

- There is lack of co-ordination and co-operation among the different research institutions and the different scientific disciplines (e.g. medicine and nutrition).
- The question of disease prevention based on nutrition is not very well covered in medical and in particular clinical research.
- A lot of research institutions in the nutritional field are classically oriented and lack of know-how and equipment in molecular biological approaches and methods. Therefore, these institutions focus their research activities on issues related to raw material quality and food processing but hardly cover physiology-oriented research topics aiming to analyse the causal relationships between a specific nutritional factor and health.
- Most of the research institutions active in food and nutrition-related research have not incorporated the advances achieved in genomics in recent years in their research activities.

Table 2: **Participation of different countries in EU-research projects at the borderline of food, nutrition and health from 1995 to 2000**

Country	Co-ordinated projects		Volume of co-ordinated projects[1]		Participation in other projects	
	Number	%	Mill. DM[2]	%	Number of institutions	%
Austria	2	1.6	3.1	1.2	11	1.5
Belgium/Luxemburg	10	7.8	22.8	9.0	24	3.3
Denmark	7	5.5	11.6	4.6	32	4.4
France	16	12.5	23.2	9.1	90	12.5
Finland	7	5.5	13.3	5.2	27	3.8
Germany	10	7.8	21.6	8.5	78	10.8
Greece	3	2.3	3.6	1.4	11	1.5
Ireland	10	7.8	29.4	11.6	26	3.6
Italy	3	2.3	8.5	3.4	58	8.1
The Netherlands	16	12.5	35.4	13.9	81	11.3
Portugal	1	0.8	0.0	0.0	11	1.5
Spain	2	1.6	3.2	1.3	41	5.7
Sweden	5	3.9	16.5	6.5	44	6.1
United Kingdom	33	25.8	61.0	24.1	110	15.3
Other countries	3	2.4	0.4	0.2	76	10.6
Total	**128**	100.0	253.5	100.0	**720**	**100.0**

1) The financial volume refers to the projects co-ordinated by institutions of the particular country. - 2) For single projects the financial volume is not available.

Source: Own investigations based on EU (2001)

Government policy

From a legal point of view, Functional Food is positioned in a transitional zone between food and pharmaceuticals. In Germany, these areas are traditionally regulated by separate institutions and are subject to different regulation regimes, so that a kind of "grey zone" with a high level of uncertainty emerges. The classification of single Functional Food products to one of the two categories is of high practical relevance due to the fact that the factual prerequisites, authorities and procedures related to market entrance of products differ between these two legislation areas. Definition problems exist for products with functions aiming to prevent nutrition-related diseases and/or to support health ("health claims"). Currently it is not allowed to use disease-related aspects in consumer information or advertising for Functional Food in Germany. In addition to German regulations, EU regulations (like e.g. the Novel Food regulation, directives related to dietary supplements) may be of relevance for the market introduction of Functional Food as well (HÜSING et al., 1999).

In Germany, research topics at the borderline of food, nutrition and health have not played a major role in public R&D funding programmes and initiatives in recent years. Since 1995 BMBF has spent around 11 % (BMBF, 2001b) of all research funds devoted to food and nutrition-related projects to this field. In 1999 DFG had a corresponding share of around 8 % (DFG, 2001, DFG, 2000a). In 1997 BMBF started an initiative for co-operative research projects of public research institutions and industry ("Leitprojekte") in the nutrition field. In this context three projects each running between 1999 and 2004 have been selected for funding with around 40 to 50 million DM. In 2001 BMBF asked for applications for networks for "molecular food and nutrition research" which should be funded for the coming 3 to 4 years (BMBF, 2001a). In addition, the DFG funded several research groups for junior scientists in nutrition research which are targeted to health aspects (DFG, 2000b).

3.4 Development block

According to the TS approach, the presence of substantial entrepreneurial activity, the need of a "censorial mass" as well as the clustering of competences are necessary prerequisites for the transformation of a knowledge and information network into a "development block" which is described as synergistic clusters of companies and technologies within an industry or a group of industries (CARLSSON and STANKIEWICZ, 1995, pp. 21 – 56). In this context three aspects of networks seem to be noteworthy with regard to the German technological system at the borderline of food, nutrition and health, namely "bridging" institutions and supporting industries, user-supplier linkages and critical mass regarding technologies and geographically.

In Germany the academic sector has played a reactive rather than a leading role in the development of Functional Food so far. On the other hand, the multinational food companies as well as the suppliers of food ingredients which have been the most important promotors of this type of food in recent years are mainly globally oriented with R&D capacities located in several EU and partly also overseas countries. Although there is a certain tradition in mostly application-oriented research among public research institutions and food industry companies in Germany, there is no specific "bridging" institution which combines the existing competences at the borderline of food, nutrition and health. The non-profit Research Association of the German Food Industry (FEI) which aims to realise application-related, co-operative research projects with the food industry and academia could fulfil parts of such an institution. Yet, over the recent 10 years, it focussed the funded research activities on process optimisation, quality improvement of food or processing steps, development of new technologies or analytical tools while research projects combining nutritional and health aspects played a minor role (FEI, 2001). The establishment of food and nutrition-related biotechnology companies is impeded by lack of specialised venture capital companies as well as low investments of other venture capitalists in this area due to the limited growth perspectives e.g. compared to the medical field (MENRAD, 2001).

There is a long tradition of intensive links between food industry companies and suppliers of food ingredients as well as processing machinery which both play a major role as innovation source in particular for SMEs. In a company survey in 1998, 31% of all food industry companies mention innovative suppliers as important prerequisite for their own innovation activities (ZEW, 2000). However, most of the main food ingredients suppliers are globally oriented, so that the market in Germany only has a limited relevance in their company strategies. In addition, globally oriented suppliers are basically interested in globally acting food industry companies to which they can sell great amount of ingredients. This implicates that only very few companies of the food industry in Germany (mainly the subsidiaries of the multinationals) can motivate their suppliers to develop and test new functional ingredients which might be of interest for the food company. Most of the small and medium-sized food industry companies (which represent by far the majority of all food companies in Germany) will not get specific support from their suppliers to develop and launch new health-related products but can buy the "standard" functional ingredients offered by the respective food ingredient companies.

In order for a technological system to function as a development block a certain number of actors as well as a certain intensity of the relationship among the various agents are necessary for generating economic activity. This refers technologically and geographically in particular in high technology fields with strong linkages to basic scientific developments. This is at least partly true for the field of health-related food products. However, there is no clear clustering of agents or competences recognisable in Germany in this field so far. This relates both to scientific institutions as well as to the food industry. The research institutions active in projects at the borderline between food, nutrition and health are scattered all over Germany and mostly devote only parts of their capacities to this field. So far there is no division of labour or clustering of competences at the different locations or institutions what seems a necessary prerequisite because rather expensive and specialised equipment as well as a certain size of the respective research groups with members of different scientific disciplines are required to be competitive on an international level. Industrial research activities in the medium-sized food industry is mainly focussed on specific production techniques or optimisation of specific processes (BMBF, 2001a) and rather isolated. In the rare case that research projects are carried out which incorporate nutritional and health aspects, these are mainly stand-alone activities without linkage to a broader network. In this sense no competence and knowledge network has developed so far in Germany, which combines the existing capacities and the available expertise in the field of health-related nutritional research.

4 Conclusions and recommendations

The analysis in the above paragraph shows significant weaknesses of the technological system at the borderline of food, nutrition and health in Germany in the generation of knowledge both in public institutions as well as SMEs of the food industry, the setting-up of knowledge and competence networks, the regulatory framework as well as in the commercialisation of existing knowledge. Strengths can be found in the strong consumer demand for this type of food which most probably will increase in the coming years as well as the availability of a "critical mass" of entrepreneurial actors (mainly the multinational food industry companies, some pharmaceutical companies as well as important food ingredient suppliers) which are able and willing to open new segments of the Functional Food market in future. The following recommendations will contribute to shape the technological system at the borderline of food, nutrition and health in Germany in order to better deal with the forthcoming challenges:

- An important basic activity with a mid-term perspective is the clarification and standardisation of the regulatory status of Functional Food in Germany and within the EU both for consumers and industrial companies as legal basis for economic activities. In addition to aspects like safety and efficacy of Functional Food (and the connected possibilities of claims which can be used in consumer information and advertising) the restrictions faced by small and medium-sized companies of the food industry should be considered during shaping the regulation in order to avoid non-achievable market entrance barriers for these companies. Some of the challenges which have to be overcome in this context are the often limited scientific knowledge concerning the efficacy of a specific functional ingredient or Functional Food product, the definition of Functional Food and their differentiation from pharmaceuticals and "conventional food" which follow different schemes of regulation, the differing regimes and practice of market approval of Functional Food in the member states of the EU as well as discussions about the nature and requirements for claims which should be allowed for Functional Food.
- Aspects of health and nutrition should have a higher relevance in public research funding programmes. In particular in existing programmes, e.g. in the biotechnology field and health research, funds should be shifted to such topics. In this context the scattered responsibilities among the ministries in Germany represent a major obstacle.
- Building up of a limited number of interdisciplinary competence centres of nutrition research focussed on specific diseases and/or groups of functional ingredients. For this purpose at least parts of the resources and capacities of existing research institutions should be shifted to these newly established centres. During this process geographical and/or technological clusters should be created in which a "critical mass" of expertise and resources are combined in order to successfully compete on an international level. This process is often hampered by the interests of scientists or existing institutions which are not willing to change their field of research. In addition, rather high financial requirements have to be fulfilled in order to realize such competence centres.
- The existing education of academic personnel should be modified thereby giving more weight to nutritional aspects in the education of physicians and introduce modern molecular methods and approaches in the education of students of nutritional sciences. Although there are initiatives of e.g. nutritional scientists in this direction they are often slowed down by the existing boundaries between different faculties and scientific disciplines at universities in Germany. In addition, there is often a differing "culture" and language between different scientific disciplines which impede interdisciplinary co-operation.
- The network-building of SMEs of the food industry, food ingredient suppliers, research institutions and supporting industries in health-related R&D should be stimulated by public funding of pilot projects in this field for a limited time period (e.g. 3 to 5 years). Furthermore, additional efforts should be taken to include industrial actors in defined research projects (like it is the case in the above mentioned "Leitprojekte" in the nutrition field) with the target to commercialise the results within a foreseeable timeframe.
- Enhanced activities are required from the food industry in Germany as well in order to successfully compete in this field in particular in an international context: the R&D investments of the food industry should not decrease but should be increased step by step in the coming years.
- Despite their limited resources SMEs of the food industry should take own activities in order to create a certain knowledge base in the area of food, nutrition and health. This "docking" competence is of particular relevance in case of R&D co-operations with other companies or research institutions.
- Industrial associations can initiate and manage research projects in which basic aspects related to food, nutrition and health are examined by competent research institutions on behalf of a cluster of SMEs. After finishing of the project the financing SMEs can jointly use the results. An interesting starting point for such activities can be the combined research projects organised by FEI which should focus to a higher extent to research topics at the borderline between food, nutrition and health.
- The same relates to clinical trials in order to prove efficacy of a particular functional ingredient which can be initiated and managed by industrial associations on behalf of interested SMEs as well.
- Public policy should support the transfer of the emerging new technologies in existing SMEs of the food industry instead of mainly focussing on founding of new companies in this field.

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