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Innovations in the food industry in Germany

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Abstract

The paper analyses the innovation system of the food industry in Germany. After an overview about the theoretical framework, knowledge generation in research organisations, the financing of such activities as well as the development of scientific knowledge with relevance for the food industry is investigated in detail followed by an analysis of the structure and innovation activities of industrial companies. Specific emphasis is laid on interactions between the different actor groups. In addition, the political and legal framework as well as food demand in Germany are analysed. The paper finalises with some conclusions for policy, industry and other actors.

Keywords: Innovation system; R&D; Food science; Food industry; Germany

1. Introduction

The food industry is one of the most important branches of the national economy in Germany and the European Union, with high relevance for employment and economic output. In addition, it plays a central role for the processing of agricultural raw materials and food supply of the population. In recent years, the food industry has been facing far-reaching technical and economic changes in the production and processing of food, as well as in society, which will have significant impacts on the entire processing chain of agricultural production, and food processing up to the distribution of food to end consumers. Examples for these changes are the opportunities and risks of novel food, new scientific and technical approaches in food processing, the impacts of structural changes in the food industry and in food retailing, the effects of food scandals and the BSE crisis, and socio-demographic developments as well as changes in consumer behaviour.

In innovation research the food industry is traditionally regarded as a sector with low research intensity (Martinez and Briz, 2000; Grunert et al., 1997; Christensen et al., 1996). However, innovations understood as new products, processes or services are an important instrument for companies in the food industry to stand out from competitors and to fulfil consumer expectations. According to the view of modern innovation research, companies almost never innovate in isolation, but their innovation activities are embedded in a network of different actors and “institutional” framework conditions. Therefore, it is not appropriate to analyse only the innovation activities of companies, but all activities in the entire innovation system starting from knowledge generation up to the market introduction and penetration of new products, processes or services should be taken into consideration. So far, such an analysis has not been carried out for the food industry in Germany or other EU countries.

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The main target of this paper is the analysis of the innovation system of the food industry in Germany. For this purpose, an overview is given about the theoretical framework outlined in economic literature. Afterwards the structure and financing of R&D activities with relevance to the food industry as well as innovation activities of food industry companies are analysed. Specific emphasis is laid on interactions between the different actor groups. In addition, the political and legal framework of food processing as well as food demand in Germany are analysed. The paper finalises with some conclusions for policy, industry and other actors.

2. Theoretical framework

Innovation is a complex phenomenon, involving the production, diffusion and translation of scientific or technical knowledge into new or modified products and services as well as new production or processing techniques. Until the 1980s, the idea of a linear sequential model of the innovation process prevailed in innovation research. According to this model, the innovation process starts with basic research which tries to analyse the scientific principles of a specific phenomenon without a specific target. This phase is followed by applied research which intends to find solutions for defined problems or targets. The successful results of this process ("inventions") are transferred into the experimental development phase aiming to develop, e.g. a prototype of a new product. Successful prototypes are transferred to industrial development and finally to the production process. Afterwards follows the market introduction and—in case of success—the market penetration of the new products. In the linear model it is assumed that there are no reciprocal interactions between research institutions and industrial research, but a linear transfer of results of basic research activities to industrial companies. This "first generation" of models of the innovation process is characterised by technology-push innovations (Rothwell, 1995). Critics of the linear model emphasise that asymmetric information, uncertainty about future developments as well as set-backs during the innovation process necessitate feedback mechanisms between the different phases. Additionally, it was criticised that "one-directional explanations of the innovative process ... are inadequate to explain the emergence of new technological paradigms" (Dosi, 1982) and that factors outside industrial companies (e.g. scientific/technological knowledge, demand conditions on relevant markets) are not considered in the model (Senker, 1995).

During the 1980s, the linear sequential model is removed by coupling models which suggest recursive and reflexive combinations of the different phases of the innovation process, thereby removing the strict time sequences between the different phases. One prominent example of this type of model is the "chain-linked model" of the innovation process suggested by Kline (1985) and described in detail in Kline and Rosenberg (1986). These authors differentiate two types of actors in their model: research and commercial companies. Both actors have access to basic or applied "knowledge" which is freely available. In the initial phase of the innovation process there are direct interactions between research and commercial companies. In the following phases of the innovation process (e.g. testing phase of a new product, production, market introduction and distribution), the internal know-how of company researchers or the freely accessible knowledge are regarded as being more relevant. There are feedback loops between the different phases of the innovation process as well as the market success of the new product, which—in case of low success rates—might result in the need for modification of the new product (Kline and Rosenberg, 1986). Another example of a feedback-oriented model of the innovation process can be found in Ropohl (1989).

The coupling models of the innovation process reflect innovation activities in a more adequate way than linear models, but they do not allow the prediction of typical time frames necessary to carry out the different steps of the innovation process. In addition, the model of Kline and Rosenberg (1986) is focused on "mature" technologies and economic fields with low research intensity, in which co-operations between research institutions and industrial companies typically have limited relevance. Therefore, it is criticised that radical innovations cannot be adequately explained by these models, because such innovations are often based on changing paradigms in scientific research carried out outside industrial companies.

Networking and recursive interactions between different types of actors, parallel developments in science, technology and product development, the strategic integration of partners (e.g. research institutions, suppliers, customers), and use of co-operations in order to overcome limitations during the innovation process or to reduce time-to-market as well as the generation of knowledge based on the principle of division of labour are predominant features of models of the innovation process suggested during the 1990s. Rothwell (1995) classified those models as “integrated models” and “systems integration and networking models”. Examples of such models can be found in Schmoch (1996) and Grupp (1997).

In summary, it can be concluded that innovation “by no means follow a ‘linear‘ path from basic research to applied research and further to development and implementation of new processes and new products. Instead, it is characterised by complicated feedback mechanisms and interactive relations involving science, technology, learning, production, policy and demand” (Edquist, 1997). In addition, innovation processes occur over time and are influenced by many factors. In consequence, commercial companies almost never innovate in isolation but they interact with “organisations” of different types (e.g. suppliers, customers, research institutions, investment companies, government agencies) and their behaviour is shaped by “institutions” as well (Edquist, 1997) which constitute constraints or incentives for innovation (e.g. laws, cultural or social rules, technical standards).

Due to their complex character, innovation activities represent an ideal area to use system theory approaches for the analysis of such processes on the level of a (national) economy. Since the 1980s, a series of “systems approaches” and empirical studies can be registered for this purpose. “National Systems of Innovation” (NSI) is the most frequently used approach of the last decade for understanding the complex relations of the innovation process. The notion of “NSI” was introduced by Lundvall (1988) (Freeman, 1995). 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), Lundvall (1988, 1992), 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). 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). 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. Because innovation involves different forms of interactive learning, Lundvall suggests to address it within a “systems approach” (Lundvall, 1992), which is common to all authors dealing with the NSI approach (Edquist, 1997). 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 homogeneous patterns of social and cultural values shaping the institutional set up of a system of innovation (Lundvall, 1992) and by the role of the state and its public policy (Edquist, 1997).

A central issue discussed in scientific literature is the question whether geographic national boundaries still can be assumed for the national systems, or whether the process of globalisation has erased them and innovation is now a global process (Ohmae, 1990). Although several studies have been published that find a high degree of globalisation of R&D (Nelson and Wright, 1992; Fransman, 1995; Archibugi and Michie, 1995), other analyses show that R&D activities are to a lower degree subject to globalisation tendencies than processes of production (Patel, 1995; Farina and Preissl, 2000). In conclusion, the representatives of the NSI approach argue that because of differences in public policies, a variety of factors in a NSI (e.g. regulation and standards, public research and education system, property rights, shaping of the financial and banking system, communication infrastructure) vary between nations (Edquist, 1997;

Nelson, 1993; Johnson, 1992; Niosi et al., 1992). Altogether, Lundvall et al. (2002) come to the conclusion "that the national level remains important for certain innovation activities".

Other critics of NSI have stressed that alternatively (or in addition to) sub-national entities, such as provinces, industrial districts or cities have become more important than the nation-state (de Bresson, 1989; de Bresson and Amesse, 1991). Therefore, systems of innovation have been studied on levels below the nation state since the 1990s. In this context, a regional perspective has been widely used, although the notion of "regional systems of innovation" is not common in economic literature. One famous example of the regional approach is Saxenian's study of the electronics industry in Silicon Valley in California and along Route 128 in Massachusetts which focuses on differences in culture and competition between the two regions (Saxenian, 1994). Other examples of regionally oriented analyses of innovation systems can be found in Cooke et al. (1996), Boekholt et al. (1998) and Fritsch and Schwirten (1999).

In addition, sectoral approaches ("'Sectoral Innovation Systems") have been introduced in economic literature as well (Breschi and Malerba, 1997) where the boundaries of the systems are endogenous, emerging from the specific context of the sector. They are based on the idea that different sectors or industries operate under different technological regimes, which are characterised by specific combinations of opportunity and appropriability conditions, degrees of cumulativeness of technological knowledge, and characteristics of the relevant knowledge base (Carlsson et al., 2002).

Another type of systems approaches focuses more on the technology itself and its mediation. The concept of "technological systems" (TS) seems to have been first used by Hughes (1983) in his study of the electrification of the US railway system during 1880 and 1930 (Carlsson and Stankiewicz, 1995). 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; Ropohl, 1998), using sometimes slightly modified variations of this approach.

TS 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). They are characterised by knowledge or competence flows rather than the flows of ordinary goods and services, i.e. they 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. The need of a "critical mass" is directly linked to the nature of innovation which is described by Dosi (1988) 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), thus requiring the interaction among agents with different competencies. 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.

All suggested approaches to analyse innovation systems emphasise the high relevance of strategic co-operation among different actors in innovation processes. In addition, the generation of knowledge and "learning" of individuals or organisations is regarded as a vital part of innovation systems as well. This focus on learning widens the perspective to include other than technological factors, such as organisational change, human capital formation and marketing issues in the analysis of innovation systems, and directs attention to actors who facilitate learning. Actors in an innovation system do not only have to learn to use the output and facilities of the system, but they also have to develop the skills to change the system according to changing economic, political, social and technological developments (Farina and Preissl, 2000). The specific role of knowledge generation in the innovation process has become even more central since the emergence of the so-called "knowledge-based economies" (OECD, 1996).

Several authors have established a taxonomy of knowledge in which they distinguish between "ideas" (i.e. knowledge which is codified and stored outside the human brain), and "skills" as knowledge which cannot be dissociated from an individual person because it is stored in his brain in form of conditions, abilities, talents, etc. (Heitor and Conceicao, 1999;

Foray and Lundvall, 1996). Codified knowledge can be transferred over long distances and across national borders (Foray, 1997) with costs often lower than the costs of production. Since codified knowledge facilitates market transactions, it can reduce uncertainties and information asymmetries between different actors and in this sense reduce learning costs (Foray, 1997) of e.g. a small or medium-sized enterprise (SME).

The second kind of knowledge, known also as tacit knowledge, consists of highly specific technological and other know-how acquired during long processes of learning. In contrast to codified knowledge, tacit knowledge ("skills") cannot be easily transferred because it has not been stated in an explicit form. Since codification is never complete, some forms of tacit knowledge will continue to play an important role (Foray, 1997), in particular in high-technology fields. On the level of an individual person, tacit knowledge can be transferred by continuous and direct contacts between individuals in the form of learning-by-doing (Arrow, 1994) or learning-by-interacting (Lundvall, 1992). In contrast, organisations can transfer non-coded, tacit knowledge via transfer of individual persons as well (Cowan and Foray, 1997). Given the persistence of a tacit share of knowledge in particular in new emerging technological fields, learning is outlined as a key factor of development for innovation systems. The system's capacity to learn in the sense of acquiring new skills is regarded as a crucial factor of competitiveness (Lundvall and Borràs, 1997). Therefore, the evolutionary approach and innovation systems literature have paid a lot of attention to formal and informal co-operation and interaction among firms (Malerba, 2002). In addition, the role of the relationships between companies and non-firm organisations as a source of innovation (Pisano, 1997; Nelson and Rosenberg, 1993), or the conditions of firm's knowledge creation (Nonaka and Takeuchi, 1995) have been emphasised in several studies.

Recent literature reviews have found several benefits from public research for innovation (Martin et al., 1996; Salter et al., 2000; Salter and Martin, 2001). These include producing new scientific information, training skilled graduates, supporting new scientific networks and stimulating interaction, expanding the capacity for problem-solving, producing new instrumentation and methodologies/techniques, creating new firms as well as providing knowledge about the social and regulatory pressures which partly determine whether innovations succeed or fail. In particular, in new technology fields (like, e.g. genetic engineering), low consumer or user acceptance can affect their trajectories significantly (GECP, 1999; Menrad, 1999).

The research organisation system has to be connected with commercial companies, so that the benefits of public research can be expressed in the economy. Much economic literature assumes that such connections are the results of "spillovers" (i.e. side effects or "externalities" of public research) (Scott et al., 2001). But a number of authors have criticised this idea as well suggesting to analyse the specific mechanisms of linkage in more detail (David and Hall, 2000; Rappert et al., 1999). The economic literature reveals a variety of channels—formal and informal, direct and indirect, deliberate and unplanned—for interactions between research organisations and commercial companies, such as codification of information or ideas (e.g. in scientific publications, patents or in form of prototypes), different forms of co-operations (e.g. joint ventures, joint research projects, personnel exchange), formal or informal contacts (e.g. meetings, conferences, informal interactions, specific networks), as well as formal contractual links (e.g. licenses, contract research, consulting).

There are no examples in economic literature which intend to analyse the innovation system of the food industry of a region or a specific country. Available studies are limited to the analysis of the innovation activities of food industry companies partly restricted to a specific sector of the food industry or to specific countries (e.g. Grunert et al., 1997; Traill and Pitts, 1998; Martinez and Briz, 2000; Traill and Meulenberg, 2002). In particular, knowledge generation in research organisations or other institutions outside the food industry is hardly covered in the available studies. On the other hand, several authors emphasise the relevance of demand-oriented aspects for the analysis of innovations in the food industry (Traill and Meulenberg, 2002; Grunert et al., 1997; Christensen et al., 1996).

Compared to other industrial branches, the food industry in Germany is characterised by a strong focus on the German market. At first glance, specific regional clusters do not exist in the food industry in Germany, so that the use of regional approaches to analyse the innovation system does not seem to be adequate. The food industry in Germany fulfils the principle requirements of the NSI approach (which can be described with its four basic concepts: innovation, learning, system and nation). In addition, particularly the knowledge generation system and the co-operation pattern of the food industry in Germany are mainly nationally-oriented. The same relates to the distribution channels of the food industry and consumer behaviour with respect to food choice and nutrition which is still characterised by strong differences and national peculiarities in Europe.

As sectoral approaches of innovation systems do not specifically consider national differences and peculiarities, they do not seem to be an optimal starting point for the analysis. In contrast, the NSI approach does include differences between different nations in its theoretical framework. However, demand-related aspects should be integrated in this approach (as it is suggested in a broad definition of NSI) as consumer behaviour in the food market determines the activities of the food industry to a high extent. Due to almost stagnant markets, product innovations of the food industry are often focussed on few growing segments of the food market. Therefore, changes of consumer behaviour are one of the main drivers of innovation activities of food industry companies and thus demand-related parameters should be included in an analysis of the innovation system of this industry. Since the food industry consists of rather heterogeneous branches, the TS approach does not seem to be a good starting point for the analysis, particularly since different new and established technologies have to be taken into account which follow partly different paradigms and trajectories (Dosi, 1988). Altogether the NSI approach seems most adequate to analyse the innovation system of the food industry in Germany while TS are an appropriate approach if specific technological innovations are concerned (Menrad, 2001).

In a "narrow" definition the NSI approach concentrates on the institutional actors involved in producing and diffusing new knowledge and technologies. Therefore, Nelson and Rosenberg (1993) 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. The following investigation of the innovation system of the food industry in Germany follow these issues, complemented by demand-related aspects.

3. Structure and financing of R&D activities

In the following section, R&D activities with relevance for the food industry in Germany are analysed, thereby focussing in a first part on research organisations which carry out such activities and in a second part on the funding opportunities for R&D activities. In addition, the development of different fields of scientific knowledge in the food and nutrition area is investigated, using a bibliometric approach.

3.1. Structure of R&D activities in Germany

R&D activities related to the food industry are carried out in a variety of organisations in Germany. This relates both to private companies as well as public research institutions. In Fig. 1, an overview is given which organisations financed and carried out such activities in the years 1999 and 2000.

A major source of innovation activities are internal R&D departments of industrial companies. The development of the R&D personnel in the food industry in Germany in the last decade is shown in Table 1. This personnel peaked in 1995 with around 2700 people and decreased to about 2300 in 1999 mainly at the expense of technicians and other personnel while the number of researchers remained relatively stable (Table 1). In 1999 R&D personnel represented around 0.4% of all employees of the food industry, compared to around 2.4% in all industries in Germany.

Information concerning the distribution of the R&D personnel among the more than 6100 companies of the food industry in Germany is limited, due to lack of adequate data. None of the main R&D centres of the food multinationals (e.g. Nestlé, Unilever, Danone, Kraft Foods, Campina) is located in Germany, but some of them have established regional development centres in this country. In addition, surveys among companies indicate that at least part of the SMEs totally lack R&D personnel or abstain from R&D activities. During a project which aimed to analyse selected regional innovation systems in eight European

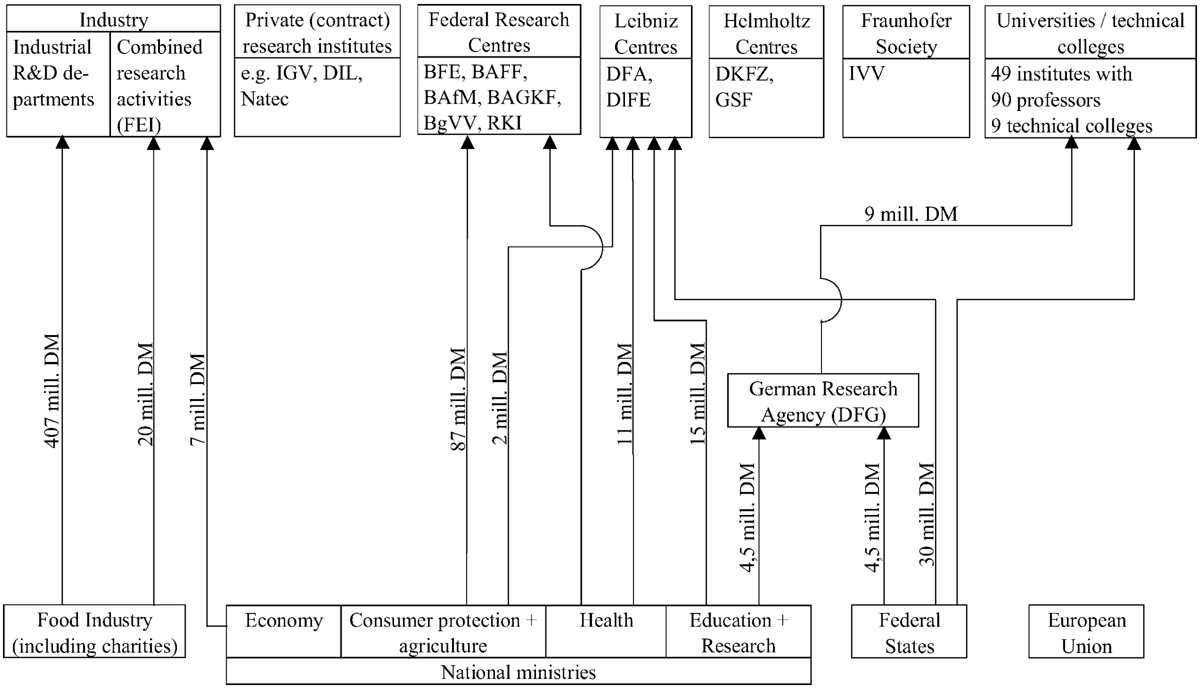

Fig. 1. Food and nutrition research in Germany in 1999/2000. *Source*: BMBF (2000, 2002a,b,c), FEI (2000) and DFG (2000, 2001).

countries,[1] 116 SMEs of the food industry in the federal states of Saxony, Baden-Wuerttemberg and Lower Saxony[2] have been surveyed concerning their innovation activities during the period 1995 to 1997. Around 34% of them reported that they had no specific personnel for R&D activities, another 41% employed up to two persons for this purpose who often dealt only part-time with R&D projects. In another survey of the bakery, meat and fish industry of the federal state of Mecklenburg-Vorpommern around 15% of the responding mostly small and medium-sized companies lacked R&D personnel (Teuscher, 2000). These findings are supported by other studies indicating that SMEs more frequently abstain from R&D activities than large companies and often lack specific R&D departments (Stockmeyer and Weindlmaier, 1999; Weindlmaier, 1998).

Due to the predominantly small and medium-sized structure of food industry companies in Germany, a specific association ("Forschungskreis der Ernährungsindustrie e.V. (FEI)) was founded in 1953 which aims to organise and carry out joint applied research projects in the field of food and nutrition. In 2001, around 50 associations of the German food industry were members in FEI which represented more than 4500 companies. In addition, 50 mostly large companies were direct members of FEI. In order to carry out research projects, FEI co-operated with around 110 research institutes of universities,

Table 1
R&D personnel in the food industry 1991–1999

Qualification	1991	1993	1995	1997	1999
Researcher	779	615	885	838	853
Technicians	858	714	1006	1016	871
Other personnel	697	755	815	686	577
Total	2354	2084	2706	2541	2301

Source: BMBF (2000) and (2002a,b,c).

[1] This survey was carried out in the context of the European Regional Innovation Survey (ERIS) jointly by the Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, the University of Hanover, the University of Cologne, and the Technical University Bergakademie Freiberg. The project was financially supported by the German Research Agency (DFG).

[2] For details concerning the structure of the sample and the survey see, e.g. Muller and Zenker (2001) and Muller (2000).

technical colleges, federal research centres or of other organisations (FEI, 2000, 2001).

Food and nutrition-related R&D projects are carried out in more than 10 private research institutes as well (Fig. 1). Often, these institutes concentrate their activities on specific branches of the food industry or they offer a peculiar set of products or services (e.g. in the field of food analytics or food engineering). One example of a private research institute is the Institute for Cereal Processing (IGV) located in Bergholz-Rehbrücke, which was founded in 1960 as a public research institute for the milling and bakery industry. After the privatisation in 1994, the institute concentrated its activities on food technology, biotechnology and renewable resources related to cereals and starch. In 2000, 50 scientific and 45 technical personnel were employed at IGV (FEI, 2000). Another private research institute is the German Institute for Food Technology (DIL) located in Quakenbrück. Since its establishment in 1985, DIL regards itself as a contract research institute for the food industry with a focus on process engineering, food physics, food microbiology and analytics. In 2000, 60 employees realised a turnover of 6 million DM (DIL, 2002). The Institute for Scientific and Technical Services (NATEC), located in Hamburg, focuses on studies and analytical services for the food, cosmetics and pharmaceutical industry (FEI, 2000).

Public research organisations play an important role as knowledge base of the food industry in Germany. Based on a long tradition, the Ministry of Consumer Protection, Nutrition and Agriculture (BMVEL) runs ten federal research centres. The main target of these centres is to provide scientific advice related to the political decisions of the federal government of Germany. The following research centres have direct relevance for the field of food and nutrition[3]:

- Federal Research Centre for Nutrition (BfE), located in Karlsruhe.
- Research Centre for Meat Research (BAFF), located in Kulmbach.
- Research Centre for Milk Research (BafM), located in Kiel.
- Research Centre for Research on Cereals, Potatoes and Fat (BAGKF), located in Detmold.

Each of these federal research centres consists of four or five institutes which are specialised in different areas. In total, the centres had a personnel capacity of around 580 full-time equivalent people of which 144 were scientists in 2000 (FEI, 2000). In addition, research activities related to food and nutrition are also carried out by the Robert Koch Institute (RKI) and the Federal Institute for Health-related Consumer Protection and Veterinary Medicine (BgVV), both located in Berlin, which are run by the Ministry of Health (Fig. 1). Relevant projects refer, e.g. to the role of nutritional aspects in the occurrence of specific diseases, the protection of consumers related to chemical or microbial food hazards or the assessment of health risks of specific ingredients.

As shown in Fig. 1, food and nutrition-related research activities are additionally carried out in research institutes of the Leibniz, Helmholtz and Fraunhofer Society. The Gottfried Leibniz Association is a joint organisation of 78 scientific research and service institutes which is equally financed by the Federal Government and the 16 federal states of Germany. The German Research Institute for Food Chemistry (DFA), located in Garching, and the German Institute for Nutrition Research (DIfE), located in Bergholz-Rehbrücke have direct relevance for the field of food and nutrition. DFA focuses its activities on the chemical composition of foods and the assessment of specific ingredients. In 2000, the institute had a staff of 53 persons and a budget of 4.2 million DM (DFA, 2002). DIfE was founded in 1992 by the federal state of Brandenburg with the target to investigate the relationships between health and nutrition. This institute is one of the rare institutions in Germany in which interdisciplinary team of nutritionists, physicians, food chemists, biochemists, molecular biologists and immunologists jointly work on this aspect. In 2000, DIfE had a permanent staff of 178 persons and an annual budget of 24.5 million DM (DIfE, 2002). Other Leibniz centres active in the fields of plant physiology, plant breeding or diabetes research carry out additional research projects related to the raw material base of the food industry or health-related aspects of nutrition.

The Helmholtz Association of German Research Centres is the biggest scientific organisation in Germany, mainly consisting of big research centres which are active in fields like, e.g. health, environment, energy or traffic. They are mainly financed by the federal

[3] Federal research centres active in the fields of agriculture, plant breeding and fisheries are not included in this list.

government (BMBF, 2000). The German Cancer Research Centre (DKFZ), located in Heidelberg, and the Research Centre for Environment and Health (GSF), located in Neuherberg, are relevant for the field of food and nutrition. The main target of DKFZ is the investigation of the emergence of cancer and related risk factors. Research projects relevant for the field of nutrition are mainly carried out in the research group "risk factors and prevention of cancer". GSF realises research activities which investigate the interaction between the health of humans and environmental factors. For this purpose 10 research topics have been defined, of which the prevention of nutrition-related diseases has high relevance for the field of food and nutrition.

The Fraunhofer Society for Applied Research is a public contract research organisation which is mainly financed by acquired research projects of private or public clients. Within the Fraunhofer Society, the Fraunhofer Institute for Process Engineering and Packaging (IVV), located in Freising, is mainly active in the field of the food industry. The around 120 employees of this institute realise applied research projects related to optimising food packaging, improving products and processes in the food industry, enhancing production-integrated environmental techniques in the food industry, as well as introducing new technologies and food ingredients. In 2000, the annual budget of IVV amounted to 17 million DM (IVV, 2002).

An important group of research institutions which carry out research projects with relevance for the food industry are universities and technical colleges. The relevant institutes or research centres are listed in the Tables 2 and 3. In 2000, food and nutrition-related research and education activities were carried out in almost 50 university institutes or professorships at 24 universities in Germany. In total around 90 professors were active in this field. Around 810 scientists (including professors) and around 440 people employed as technical assistants or in other functions were working in the relevant institutes (Table 2). Besides, there are education and research capacities in food technology and nutritional sciences established at nine technical colleges with around 120 persons active as scientists or other staff (Table 3).

Besides a limited number of researchers, there are structural deficits in the science base of food and nutrition in Germany (BMBF, 2001; DFG, 1999; Hüsing et al., 1999).

- There is lack of co-ordination and co-operation among the different research institutions and the involved scientific disciplines (e.g. technological or engineering disciplines, nutrition, medicine, social sciences).
- The question of disease prevention based on nutrition is not very well covered in medicinal and in particular clinical research. The same relates to the investigation of the role of nutritional factors in the emergence of specific diseases. In this context, lack of interdisciplinary research teams consisting of e.g. nutritionists, physicians, food chemists, biochemists, molecular biologists and immunologists has to be stated.
- A lot of research institutions in the nutritional field are classically oriented and lack 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.
- Most of the research institutions active in food and nutrition-related research have not incorporated the advances achieved in genomics research in recent years in their research agenda.

3.2. Development of scientific knowledge in the food and nutrition area

The development of scientific knowledge in the food and nutrition area was analysed with the help of a bibliometric approach. This analysis was carried out using the online version of the Science Citation Index (SCI) as provided by the host STN. The SCI covers a broad range of scientific disciplines. Its specific advantage for institutional analysis or data gathering based on institutional affiliation is that the addresses of all the authors that contributed to the publication and their institutional affiliation are searchable in the database. The starting point for the bibliometric work was the definition of the field under analysis. For this purpose, the scientific journals covered in SCI were screened for relevance for food and nutritional sciences and a set of journals was defined which covered this area. Publication data, representing one form of

Table 2
University institutes in food and nutrition research in 2000

Name of the university	Name of the institute/centre	Number of employees	
		Scientists	Technical/ other personnel
Free University of Berlin	Institute for Food Hygiene and Technology	10	11
	Institute for Meat Hygiene and Technology	10	8
Technical University of Berlin	Institute for Food Technology I	12	8
	Institute for Food Technology II	7	8
	Institute for Food Chemistry	17	11
University of Bonn	Institute for Nutrition Research	9	11
	Institute for Food Technology and Chemistry	15	12
	Institute for Food Technology	19	5
Technical University of Bruinswick	Institute for Physical and Theoretical Chemistry	9	3
	Institute for Food Chemistry	17	7
	Institute for Biochemistry and Biotechnology	16	11
Technical University of Dresden	Institute for Food and Bioengineering	19	7
	Institute for Food Chemistry	10	7
University of Erlangen-Nuremberg	Institute for Pharmacy and Food Chemistry	9	n.a.
University of Frankfurt	Institute for Food Chemistry	12	3
University of Gießen	Institute for Nutritional Sciences	18	21
University of Hamburg	Institute for Biochemistry and Food Chemistry	25	7
University of Halle-Wittenberg	Institute for Nutritional Sciences	8	9
Veterinary University of Hanover	Department of Chemical Analytics and Endocrinology	6	4
	Department of Hygiene and Technology of Milk	6	5
	Department of Food Hygiene and Microbiology	2	n.a.
	Department of Food Toxicology	14	4
	Department of Food Sciences, Meat Hygiene and Technology	8	20
University of Hanover	Institute for Food Chemistry	10	3
	Institute for Food Sciences	24	10
University of Hohenheim	Institute for Biological Chemistry and Nutritional Sciences	41	15
	Institute for Food Technology	53	37
	Institute for Food Chemistry	14	7
University of Jena	Institute for Nutritional Sciences	53	20
University of Kaiserslautern	Department of Food Chemistry and Environmental Toxicology	19	5
Technical University of Karlsruhe	Institute for Food Engineering	13	7
	Institute for Food Chemistry	20	n.a.
University of Kiel	Institute for Nutrition and Food Sciences	19	7
University Leipzig	Institute for Food Hygiene	6	7
University of Munich	Institute for Hygiene and Technology of Foods derived from Animals	21	29
	Institute for Physiology, Physiological Chemistry and Animal Nutrition	11	3

Table 2 (*Continued*)

Name of the university	Name of the institute/centre	Number of employees	
		Scientists	Technical/ other personnel
Technical University of Munich	Professorship of Brewery Technology and Food Packaging	10	3
	Professorship of Energy and Environmental Technologies of the Food Industry	15	2
	Professorship of Technical Microbiology	18	3
	Institute for Nutritional Sciences	22	12
	Institute for Food Chemistry	29	6
	Institute for Food Technology	23	12
	Research Centre for Milk and Food Weihenstephan	61	49
University of Münster	Institute for Food Chemistry	10	4
University of Potsdam	Institute for Nutritional Sciences	9	8
	Professorship for Physiology and Nutrition	4	4
	Professorship for Biochemistry of Nutrition	3	4
University of Wuppertal	Institute for Food Chemistry	10	2
University of Würzburg	Institute for Pharmacy and Food Chemistry	16	2
Total		812	443

Source: FEI (2000) and own investigations.

scientific output created, was collected for the food and nutrition area between 1990 and 2001. In general, total publications for each country were retrieved.

Different categories of research have been defined, in order to structure the publications related to food and nutrition research. For this purpose, the selected scientific journals were assigned to a specific research category, thereby avoiding overlaps between the different categories. The publications in the selected journals form the basis for the development of the respective category. Two types of categories have been defined: (i) important branches of the food industry and (ii) general research topics which have relevance for all or at least several branches of the

Table 3
Technical colleges in food and nutrition research in 2000

Name of technical college	Name of department	Number of employees	
		Scientists	Technical/other personnel
Hochschule Bremerhaven	Food Technology	7	2
FH Fulda	Household and Nutrition	10	9
	Food Technology	13	2
FH Hamburg	Nutritional Sciences	8	3
Hochschule Anhalt (FH)	Food Technology, Biotechnology and Food Engineering	6	n.a.
FH Lippe	Food Technology	7	5
FH Münster	Nutritional Sciences	7	
FH Neubrandenburg	Food Technology	16	5
FH Osnabrück	Nutritional Sciences	7	n.a.
FH Trier	Nutritional Sciences and Household Technologies	12	4
Total		93	30

Source: FEI (2000) and own investigations.

food industry. The following categories have been defined in the first group: food general, meat/fish, dairy, cereals/starch/sugar, fruit/vegetables, oil/fat and beverages. Nutrition general, clinical nutrition, health and nutrition, process optimisation (including new technologies), food structure (including quality improvement of food and new ingredients), food safety (including the development of new diagnostic tools for this purpose) and other aspects (e.g. environmental aspects, consumer issues) represent the defined categories of the second type.

The world-wide number of scientific publications in the field of food and nutrition increased by 64% between 1990 and 2001 (Fig. 2). With more than 18,200 publications the highest number has been identified in the year 2000. With the exception of the years 1994 and 1998, a relatively steady growth in publications can be observed during the last decade. The decreasing figures in 1994 and 1998 are mainly caused by single journals in the area of health and nutrition, which published only around 10% of the publications compared to the surrounding years. The falling number of publications in 2001 is mainly due to the fact that this year was not totally covered in the SCI database at the time of analysis.

The number of publications in the defined branches of the food industry stagnated around 6000 during the last decade (Fig. 2). Due to the increasing trend in all publications the proportion of branch-related publications decreased from around 53% in 1990 to 33% in 2001. All defined branch-related articles excluding oil/fat and beverages were affected by the falling relevance. On the other hand, most of the defined general research issues showed increasing absolute numbers of publications and increased their relative weight during the last decade. This related in particular to the area of health and nutrition, which accounted for less than 7% of all publications in 1990 and increased its proportion to almost 25% in 2001. Other growing research fields were process optimisation and new technologies, which increased its percentage from 5% in 1990 to more than 8% in 2001 and the area of food safety (including the development of analytical tools for this purpose), which rose from around 5% in 1990 to 7% at the end of the decade. Publications related to food structure, optimisation of food products and new ingredients slightly increased their relevance and accounted for almost 12% of the world-wide publications in the food and nutrition area in 2001.

The development of the country relevance in publications related to food and nutrition is shown in Fig. 3. During the 1990s, the EU gained relevance in this area mainly at the expense of the USA. While in 1990 around 40% of all publications came from the USA and 28% from the EU, around 33% of all publications were published by US authors and almost 38% by EU scientists at the end of the decade. Japan slightly increased its percentage of publications (to 8% of the world-wide publications in 2001) and Canada showed a moderate decrease (to 5% in 2001) (Fig. 3). Within the EU, Germany had the lowest growth rate for food and nutrition-related publications among the consid-

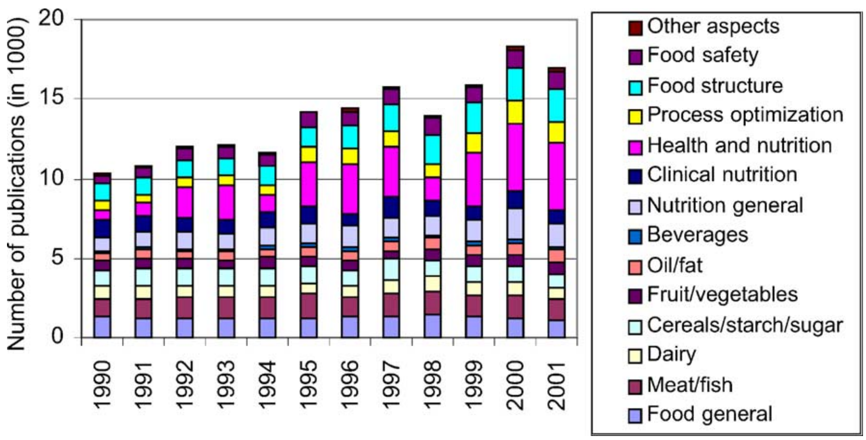

Fig. 2. World-wide scientific publications in the food and nutrition field from 1990 to 2001. *Source*: Own investigations.

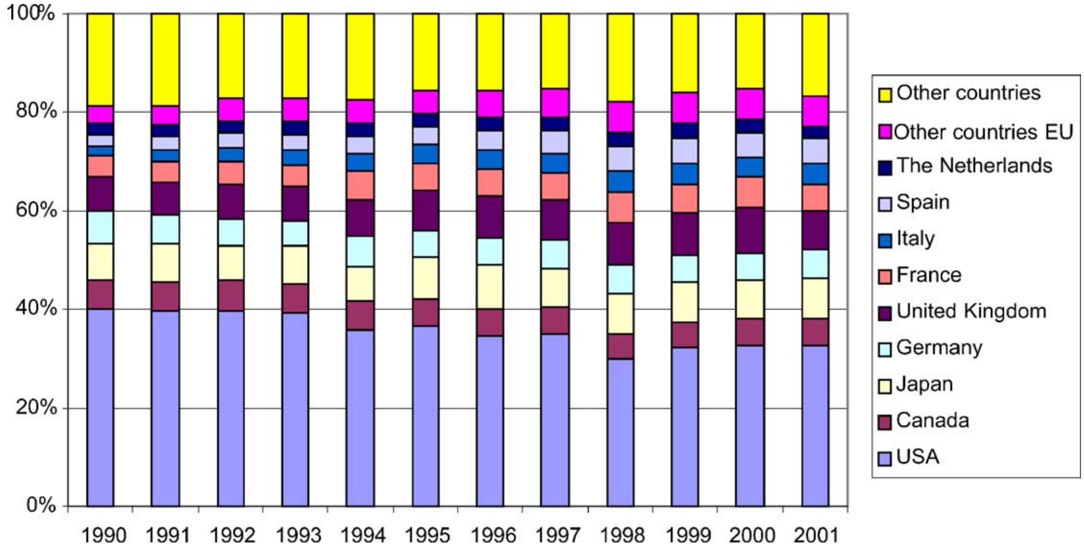

Fig. 3. Relative weight of selected countries in scientific publications in the food and nutrition field. *Source*: Own investigations.

ered countries during the last decade. Therefore, Germany slightly lost relative weight from 6.5% of the world-wide publications in 1990 to 5.9% in 2001. Scientists from the UK frequently published the highest number of articles within the EU and were responsible for almost 8% of the world-wide publications in 2001. During the last decade, Italy and Spain doubled their relative weight, both reaching almost 5% of the world-wide publications in 2001 (Fig. 3).

Another characteristic of the research activities in the food and nutrition field in Germany is the high relevance of branch-related publications, e.g. compared to the world-wide or EU average (Fig. 4). While on a global basis such publications accounted for 35% of all publications from 1999 to 2001 (and in the EU for 37% of all publications), they had a overproportional weight (45%) in Germany during the time period analysed. This is mainly caused by the fields of meat/fish as well as cereals/starch/sugar, which both had a 4 to 5 percentpoints higher relevance in Germany than in the EU average. Given the decreasing numbers of world-wide publications in both areas, it can be concluded that German scientists are overproportionally active in fields which showed decreasing relevance. On the other hand, German scientists have not shifted to the same extent to strongly growing fields like health and nutrition (17.7% of the publications from 1999 to 2001 compared to 20.7% in the EU) or food safety (5.3% compared to 6.2% in the EU) like their EU colleagues. This relates in particular to the UK where branch-related publications accounted for less than 26% and health and nutrition-related research topics alone achieved a weight of more than 30% from 1999 to 2001. All the other EU countries analysed (excluding France) have focussed their research activities to a higher extent on the growing fields of food and nutrition research than Germany (Fig. 4).

3.3. Financing of R&D activities in Germany

The food industry in Germany and in other European countries is traditionally regarded as an industry with low R&D intensity. The development of the budget for R&D activities of the food industry in Germany in the last decade is shown in Table 4. Due to economic recession tendencies, a decline in the R&D budgets was registered at the beginning of the 1990s. The following high jump to 475 million DM in 1995 is partly caused by modifications in the statistical investigation of the data (BMBF, 1996, 2000). In contrast to other industries, the food industry reduced their R&D budgets in the following years. In recent 3 years of the decade, another increase of R&D budgets can be registered to 489 million DM in 2000. In the 1990s between 87 and 89% of the R&D budgets of the German food industry were devoted to internal R&D activities,

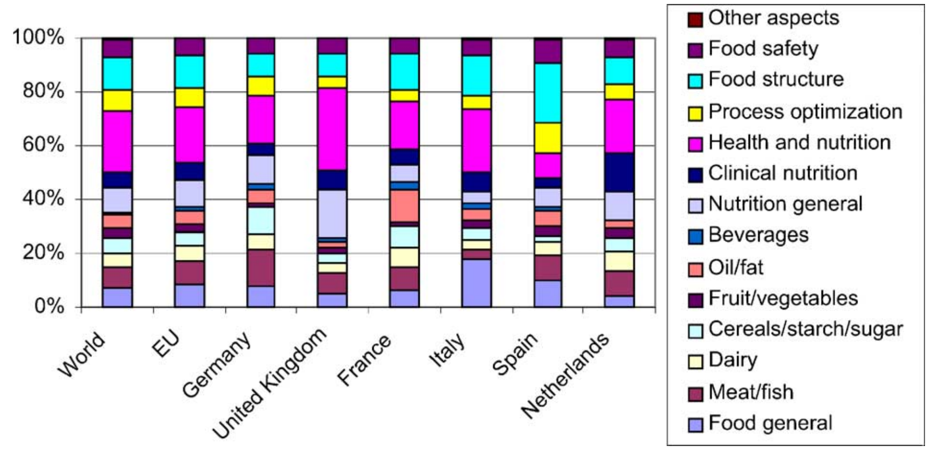

Fig. 4. Relevance of different categories in food and nutrition research in selected EU member states from 1999 to 2001. *Source*: Own investigations.

Table 4
Budget for R&D activities of the food industry in Germany 1991 to 1999 (million DM)

Year	Internal projects	Joint projects	External projects	Total
1991	329	20	26	375
1993	301	16	20	337
1995	408	17	50	475
1997	363	8	45	416
1998	n.a.	n.a.	n.a.	422
1999	407	20	42	469
2000	n.a.	n.a.	n.a.	489

Source: BMBF (1996, 2000, 2002a).

around 2–5% were used for joint research projects of industry companies and research institutions, and 6–11% for external (contract) research (Table 4). Compared to other industries in Germany the food industry spends low financial resources on R&D activities. In 1999, the food industry was responsible for 0.6% of all funds devoted to R&D activities of the German industry compared to 9.7% regarding turnover and 8.6% regarding employees (BMBF, 2000; BMELF, 2000). Consequently, the R&D intensity[4] of the food industry is frequently one of the lowest among all industries (BMBF, 2000, 2002a). In 1999, the R&D intensity of the food industry reached 0.4%[5] compared to 3.5% in all industries in Germany (BMBF, 2002a).

Despite the low R&D intensity of the food industry in Germany, there are relatively high differences among the companies. In company surveys generally less than 20% of the companies answer that they spend more than 1% of their turnover on R&D activities. To this group often belong large food multinationals (like, e.g. Nestlé, Unilever, Groupe Danone) (Weindlmaier, 2000). In 1995 around 66% of the R&D budget of the entire food industry in Germany was used in large companies (Stifterverband für die Deutsche Wissenschaft, 1999). On the other hand, around 20% of the companies abstain from R&D activities (Teuscher, 2000; Weindlmaier, 2000).

The research activities of FEI are jointly financed by the member associations and companies as well as the Federal Ministry for Economic Affairs. While the public funds have increased from around 3.5 million DM in the mid 1990s to around 7 million DM at the end of the decade, the industrial funds rose from around 8 million DM to 20 million DM during the same period (Fig. 1). This means that the joint research projects organised by FEI are financed to around 75% by the industry. The development of important thematic areas in these projects is shown in Fig. 5. It clearly indicates that health and nutrition-related research played

[4] Percentage of R&D expenses related to the turnover of an industrial branch.

[5] Only the turnover of those companies is considered which carry out R&D activities.

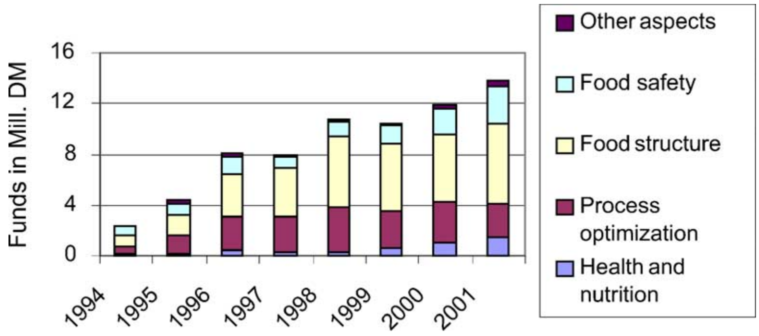

Fig. 5. Thematic areas in research projects of FEI during 1994 to 2002. *Source*: Own investigations based on FEI (2001).

a minor role in projects financed by FEI. The projects financed by this organisation were dominated by research in the fields of food structure (including quality improvement of food and new ingredients) and process optimisation (including new technologies). Both areas are of major interest for food companies in order to improve product quality or increase competitiveness by optimised production procedures. Food safety issues gained increasing interest in particular in recent years, probably caused by several food scandals and increasing consumer sensitivity.

The financing of food and nutrition-related research activities of federal research centres, institutes of the Leibniz Association as well as Helmholtz centres cannot be investigated in detail since for most institutes only total budgets are available, but in particular federal research centres run by the Ministry of Health (RKI, BgVV) and Helmholtz centres (DKFZ, GSF) are only partly active in food and nutrition research. It is estimated that BMVEL spends around 100 million DM annually for food and nutrition-related research (BMBF, 2000). The vast majority of these funds is devoted to the four federal research centres (BfE, BAFF, BfAM, BAGKF) in this area: in 1999 around 87 million DM of institutional funds were provided for this purpose (Fig. 1). The proportion of institutional funds given from BMG for food and nutrition-related research cannot be quantified, but it can be assumed that only a limited part of the total budget of RKI and BgVV of 194 million DM in 1999 was targeted to this area. Food and nutrition-related research activities of the Leibniz institutes were financed with 2 million DM by BMVEL, 11 million DM by BMG and 15 million DM by BMBF and additionally with 30 million DM from the federal states (e.g. Bavaria, Brandenburg) in which the relevant institutes are located (Fig. 1).

In addition to the institutional funds shown in Fig. 1, BMBF finances food and nutrition-related research projects in specific programmes. In 1997, BMBF started an initiative for co-operative research projects of public research institutions and industry ("Leitprojekte") in the nutrition field. Another example are the "networks of molecular nutrition research" established in 2002, in which the relationship between health and nutrition should be investigated in interdisciplinary research consortia of nutritional scientists and health professionals (BMBF, 2002b). In addition, food and nutrition-related research projects are funded in other programmes of BMBF as well.

Based on a keyword-search strategy, food and nutrition-related projects which have been funded in programmes of BMBF were selected from a publicly available database of the Ministry ("Förderkatalog") (BMBF, 2002c) for the last decade. In total, BMBF funded 178 projects with a financial volume of 60.88 million DM between 1990 and 2001. Until 1995 in which annual funds stagnated at around 6 million DM per year, a strong reduction of annual funds (to around 4 million DM) was registered in 1996 and 1997. Since this time period the available funds for food and nutrition-related research nearly tripled and reached 12.8 million DM in 2001 (Fig. 6). In contrast to the development in scientific publications (see Section 3.2), projects funded by BMBF focussed to a relatively low extent on health and nutrition or analyses of food structure (including quality improvement of food and new ingredients). One important field of projects financed by BMBF was process optimisation

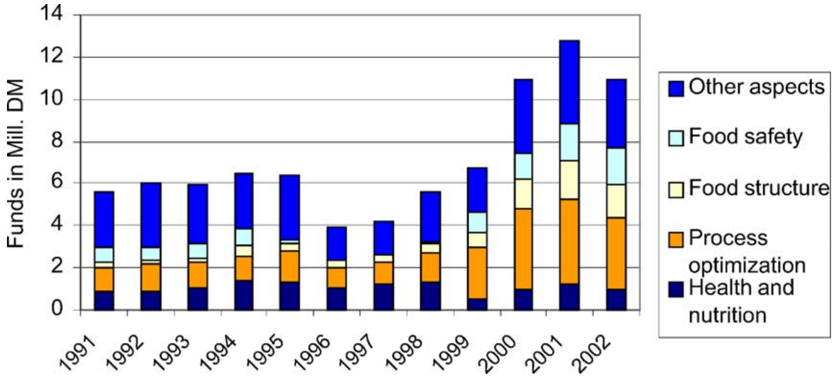

Fig. 6. Thematic areas in research programmes of BMBF during 1991 to 2002. *Source*: Own investigations based on BMBF (2002c).

and new technologies which also gained relevance since the mid 1990s. Food safety (including the development of diagnostic tools for this purpose) had a certain relevance at the beginning of the decade and increased its proportion again at the end of the 1990s, mainly due to high public interest in this issue (Fig. 6). Other aspects, which still amounted to one third of the funds, covered a wide range of different issues like impacts and risk assessment of new technologies, environmental issues related to the food industry, consumer behaviour studies or qualification aspects.

The participation of different types of organisations in the projects funded by BMBF between 1990 and 2001 is shown in Table 5. Around 37% of these projects were run by industrial companies. Related to the number of projects, SMEs had almost the double weight than large companies. However, the relevance of both groups almost equalled if the financial volume of the projects was concerned (Table 5). The most important group of participants were universities and technical colleges with almost 40% of the projects and 37% of the funds. Other public research institutions like federal research centres, Leibniz institutes or Helmholtz centres participated only with single projects in the BMBF programmes (Table 5).

The food and nutrition-related research expenditures of the German Research Agency (DFG), which is the main source for financing of research projects of universities in Germany, was investigated by identifying the realised research projects in this field. In total, six structural research initiatives (i.e. one “Sonderforschungsbereich”, three “Graduiertenkollegs”, two “Innovationskollegs”) were registered in this field which were financially supported with almost 6 million DM in 1999 (DFG, 2000). In addition, 20 stand-alone research projects were identified (DFG, 2001), for which a funding volume of 3 million DM was estimated. In total,

Table 5
Participation of different organisations in research projects funded by BMBF between 1990 and 2001

Organisation	No. of projects	%	Financial volume (million DM)	%
Large companies	23	12.9	8.62	14.2
SMEs	43	24.1	9.27	15.2
Private research institute	11	6.2	3.86	6.3
Federal research centres	2	1.1	0.6	0.9
Leibniz centres	2	1.1	7.06	11.6
Helmholtz centres	4	2.2	1.59	2.6
Fraunhofer institutes	9	5.1	3.91	6.4
University/technical colleges	71	39.9	22.28	36.6
Other organisations	13	7.3	3.69	6.1
Total	178	100	60.88	100

Source: Own investigations based on BMBF (2002c).

the DFG spent around 9 million DM on food and nutrition-related research, which were jointly financed by BMBF and the 16 German federal states (Fig. 1).

An additional financial source for scientists and companies in Germany are research programmes of the European Union (EU). Within the Fifth Framework Programme the key action "food, nutrition and health" had particular relevance for food and nutrition-related research. This key action was financed with a total of 546 million DM for 4 years until 2002 (EU, 2000). Between 1995 and 2000, 1017 projects in the food area were registered which have been funded by the EU. Research organisations or companies located in Germany participated in 38.8% of these projects. Compared to neighbouring fields (like, e.g. agriculture, life sciences, medicine/health) this represents a below average participation of German organisations in the field of food and nutrition (Menrad, 2001).

4. Structure and innovation activities of food industry companies

The food industry is one of the most important industries in Germany. An overview of the development of this industry since the reunification of Germany is given in Table 6. Concerning the annual turnover as well as the number of employees, the food industry is placed at number four among all industries in Germany. With a turnover of around 235.5 billion DM in 2000, the food industry was responsible for 9.3% of the total turnover of all industries in Germany. In the around 6100 business units[6] more than 554,000 people were employed in 2000, representing 8.8% of all industry employees in Germany (Deutscher Fachverlag, 2001).

Due to several changes in the sample of reporting companies it is not feasible to totally compare the key figures shown in Table 6, but some trends can be derived despite these statistical modifications. Since 1991 the number of business units and employees decreased significantly in the food industry in particular in the eastern federal states of Germany. The increase of business units and employees in 1997 and 1999 is caused by extensions in the sample of reporting companies (BMELF, 2000), but it can be assumed that this modification eclipses a further moderate decline of the respective figures. During the 1990s a relatively low increase of 9.8% in nominal turnover was registered for the German food industry. The turnover per employee in the food industry stagnated around 420,000 DM since the mid-1990s, but exceeded the average figure of all industries by 60,000 DM. In 2000, the food industry exported goods valued at 28.5 billion DM, of which 70% were targeted to other countries of the EU. The export rate of the food industry in Germany increased during the 1990s and reached 12.1% in 2000, but is still far below the average of all industries with an export rate of more than 36% in Germany (Statistisches Bundesamt, 2001).

Despite some mergers and company take-overs among food multinationals which gained high public interest (e.g. Unilever/Bestfoods, Nestlé/Ralston Purina, Kraft Foods/Nabisco), the food industry in Germany is still characterised by a high relevance of SMEs. In September 1999, 76.7% of the 6160 business units employed less than 100 persons, 20.9% between 100 and 500 persons and 2.3% more than 500 persons. The latter group had 20.4% of all employees and achieved 22.4% of the total turnover of the food industry in Germany (Deutscher Fachverlag, 2001). The proportion of large companies (with more than 500 employees) in the food industry is significantly below the average for industry in Germany, in which this group had 45% of all employees and was responsible for 55% of the turnover in 1999 (Statistisches Bundesamt, 2000). According to estimations of business consultants and investment banks it is expected that the number of food industry companies will decrease by around one third in the coming decade in Germany (LZ, 2000).

The food industry in Germany consists of rather heterogeneous branches. Therefore, an overview of important branches of this industry in 2000 is given in Table 7. The top three branches by turnover—slaughterhouses and meat processing companies (42.4 billion DM), the dairy industry (41.0 billion DM) and the production of beverages (39.8 billion DM)—achieved more than 52% of the total turnover of the food industry in Germany. The turnovers of the following branches (bakery, confectionery, processing of fruits and vegetables, etc.) were significantly below those of the top three branches

[6] In general, business units with more than 20 employees are considered.

Table 6
Key figures of the food industry in Germany since 1991

Year	Number of business units	Number of employees (1000)	Turnover		Export rate (%)
			Billion DM	Per employee (1000 DM)	
1991	5606	623.1	214.3	344	–
1992	5415	573.9	218.4	381	–
1993	5253	545.5	215.8	396	8.9
1994	5199	531.9	217.7	409	9.4
1995	5085	524.5	221.0	421	9.8
1996	5037	518.2	222.5	429	10.4
1997	6144[a]	551.7	231.0	419	10.9
1998	5911	544.1	228.6	420	11.4
1999	6145[b]	550.5	228.0	414	11.4
2000	6136	554.1	235.5	425	12.1

Source: BMELF (1996, 2000) and Deutscher Fachverlag (2001).

[a] In 1997, the number of reporting companies was extended, including business units which recently belonged to crafts units.

[b] In 1999, some smaller units in the eastern part of Germany were included in the sample of reporting companies (BMELF, 2000).

(Table 7). With more than 184,000 people, around one third of all employees of the food industry were working in the bakery industry in 2000, followed by slaughterhouses and meat processing companies and the production of beverages. A labour efficiency above the overall average of the food industry was registered in the dairy industry, the production of beverages, starch processing and the sugar industry (Table 7).

Innovation activities in the food industry can be analysed on different levels and with differing methodological approaches. In the following the results of investigations of "new product introductions" in food retailing stores, the data collected by specialised journals or market research institutes concerning product innovations of the food industry as well as surveys among food industry companies in Germany are presented, in order to get as clear a picture as possible of the different facets of innovation activities of this industry.

The market research institute MADAKOM GmbH, located in Cologne, investigates in a scanner-based sample of around 200 food retail shops of 30 retail companies the launch of "new products" in food retailing stores in Germany. Since the investigation is based on the EAN code of the products, each product with a new EAN-code is considered as an "innovation", i.e. each modification, e.g. in the packaging or other minor changes in the product design leading to a new EAN-code, are included in this investigation. The number of "new products" as defined

Table 7
Key figures of selected branches of the food industry in Germany in 2000

Branch of the food industry	No. of business units	Employees		Turnover	
		No.	%	Billion DM	%
Slaughterhouses and meat processing	1363	112,627	20.3	42.4	18.0
Processing of fruit and vegetables	322	28,246	5.1	14.5	6.2
Dairy	286	41,142	7.4	41.0	17.4
Mills, starch processing	108	10,336	1.9	6.8	2.9
Bakery	2489	184,169	33.2	24.7	10.5
Sugar industry	38	6684	1.2	6.2	2.6
Confectionery	150	30,710	5.5	14.5	6.2
Beverages	772	71,152	12.8	39.8	16.9
Other branches	608	69,567	12.5	45.5	19.3
Food industry total	6136	554,633	100.0	235.4	100.0

Source: Deutscher Fachverlag (2001).

by MADAKOM increased by 37% between 1998 and 2001 and reached the level of almost 32,500 products (Madakom, 2001). During this period between 50 and 67% of the newly launched products have been withdrawn within 1 year from the food retailing shelves, indicating the high competition in this field. After 3 years, the "survival" rate of the new products tends towards the 25% level (Madakom, 2001). This high rate of product failure in food retailing is supported by other authors as well (Mehler, 1997; Martinez and Briz, 2000; Behrs Verlag, 2002) and mainly caused by limited sales and shelve areas in food retailing and saturated food markets with low growth rates in Germany.

In 2001, almost 21,000 "new" food products according to the MADAKOM definition were launched in the German market. Taking into account the total number of more than 124,000 products, this equalled an innovation rate of 16.9% (Table 8). More than 14,100 of these products have been withdrawn within 1 year from the market, resulting in a slightly higher retraction rate for food products compared to non-consumer goods sold in retail stores (Madakom, 2001). There were significant differences between different food categories concerning innovation and retraction rates without following a specific pattern. High innovation rates of more than 20% were observed in non-alcoholic beverages, beer and wine, delicacies as well as salted and sweet biscuits. Innovation rates below 10% were registered for meat and fish products, dietetic foods and bakery additives. In 2001, spirits, beer and wine as well as spices had 1-year retraction rates of more than 75% compared to dairy products, cheese and baby food with retraction rates below 50% (Table 8). In order to smooth peculiarities caused by a specific year, the average retraction rates of the years 1998–2001 have been included in Table 8 as well which mainly support the findings of the year 2001.

Table 8
New food products in food retailing stores in Germany in 2001

Food category	Total number of products	New products	Innovation rate (%)	Withdrawn products 2001	Retraction rate 2001 (%)	Average retraction rate 1998– 2001 (%)
Baby food	1160	163	14.1	69	42.3	35.1
Dairy products	5666	852	15.0	407	47.8	42.4
Cheese	3056	526	17.2	203	38.6	48.9
Meat, sausages, fish	4601	439	9.5	275	62.6	59.5
Bread and cakes	4019	670	16.7	453	67.6	60.5
Cereals	1515	297	19.6	170	57.2	52.0
Marmelade	2932	499	17.0	358	71.7	61.9
Salted biscuits	2251	464	20.6	249	53.7	52.5
Sweet biscuits	4183	840	20.1	604	71.9	69.1
Confectionery	4364	847	19.4	499	58.9	58.7
Chocolates	6265	1152	18.4	813	70.6	69.7
Pre-prepared food	3183	525	16.5	300	57.1	51.3
Canned food	7066	916	13.0	540	59.0	57.2
Frozen food	7292	1217	16.7	683	56.1	52.7
Dietetic food	2116	143	6.8	92	64.3	49.5
Pasta, rice	3736	673	18.0	423	62.9	61.6
Fat, spreads	1705	261	15.3	163	62.5	64.7
Soups, sauces	3325	523	15.7	343	65.6	56.4
Spices	8531	943	11.1	715	75.8	64.0
Delicacies	2306	488	21.2	309	63.3	52.4
Bakery additives	2774	271	9.8	177	65.3	53.2
Hot beverages	3012	494	16.4	291	58.9	57.4
Non-alcoholic beverages	8904	2011	22.6	1266	63.0	53.1
Beer, wine	23,504	4876	20.7	4070	83.5	72.2
Spirits	6556	834	12.7	682	81.8	74.5
Total	124022	20924	16.9	14154	67.6	n.a.

Source: Madakom (2001).

Several market research institutes as well as specialised journals in the food area collect information on product innovations of the food industry in Germany. These institutions try to consider products with a higher degree of novelty than the MADAKOM investigations without defining the "degree of novelty" in detail. For the years 1993 and 1994, 1662 product innovations were recorded in the German food industry with great differences between the various industry branches (Hermann, 1997; Hermann et al., 1996). According to investigations of the food journal Lebensmittel-Praxis the number of newly launched food articles decreased from around 1300 in the mid 1990s to around 1050 products at the end of the decade (Table 9). The highest number of new products was registered in beverages, confectionery, snacks, dairy products and frozen food which all showed declining trends in recent 5 years.

The market research institute Datamonitor continuously collects information about product innovations in the food industry in more than 50 countries. An overview about the product innovations in Germany collected by this institute between mid 1999 and mid 2001 is given in Table 10. During this period 1579 new food products were introduced in the German market. This figure is slightly lower than those collected by Lebensmittel-Praxis (taking into account a 2-year period), but can be explained by the absence of some product groups (e.g. meat, fish, fruits, vegetables) in the Datamonitor data. The highest number of product innovations was observed in dairy, confectionery and non-alcoholic beverages (Table 10), underlining the findings of the other studies. Around 56% of the product innovations of 1999–2001 have been launched by large companies with more than 500 employees (Table 10). Regarding the different food categories, large companies showed a high relevance in innovations in baby food, sauces, frozen food and dairy products, whereas SMEs had a specific relevance in innovations in all types of beverages (Table 10).

Another source of information about innovation activities of food industry companies are surveys which are carried out continuously or for a specific purpose by different institutions. Since 1993, the Centre for European Economic Research (ZEW), located in Mannheim, has been investigating innovation activities of the processing industries in Germany. As shown in Fig. 7, a decline in the percentages of innovative firms, product and process innovations was registered in the food industry until the mid-1990s, afterwards a strong increase can be observed in all types of innovation activities. In 1999, the proportion of innovative firms in the food industry reached 62%, a decrease of 6 percentpoints compared to the previous year. In

Table 9
New food products in Germany 1995–2000

Product group	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000
Beverages	234	308	207	216	173
Confectionery, snacks	216	209	190	170	188
Dairy	241	190	139	157	120
Frozen food	160	187	110	108	119
Meat, poultry	101	84	87	77	76
Delicacies	63	65	69	55	49
Pre-prepared products	53	52	24	41	45
Animal feed	28	13	37	69	24
Bread, bakery	27	28	22	28	29
Cereal products	43	52	66	65	80
Dietary products	40	36	31	32	29
Sauces, spices	31	26	22	24	17
Baby food	44	33	48	66	49
Fish	15	17	15	16	8
Fruit and vegetables	23	33	19	21	27
Cereals	–	–	–	–	19
Total	1316	1333	1096	1145	1052

Source: Deutscher Fachverlag (2001).

Table 10
Product innovations in Germany 1999–2001

Food category	New products		Large company		SME	
	Number	%	Number	Proportion (%)	Number	Proportion (%)
Baby food	44	2.8	44	100.0	–	–
Dairy	250	15.8	156	62.4	94	37.6
Bakery	197	12.5	113	57.4	84	42.6
Pasta and rice	19	1.2	10	52.6	9	47.4
Confectionery	250	15.8	135	54.0	115	46.0
Canned food	50	3.2	27	54.0	23	46.0
Chilled food	69	4.4	41	59.4	28	40.6
Frozen food	157	9.9	115	73.3	42	26.7
Sauces	52	3.3	39	75.0	13	25.0
Snacks	42	2.7	22	52.4	20	47.6
Hot beverages	67	4.2	25	37.3	42	62.7
Non-alcoholic beverages	228	14.4	104	45.6	124	54.4
Beer	97	6.1	32	33.0	65	67.0
Alcoholic beverages	57	3.6	23	40.4	34	59.6
Total	1579	100.0	886	56.1	693	43.9

Source: Own investigations based on Datamonitor (2001).

both years, 60% of the surveyed companies launched product innovations (Fig. 7). The high relevance of product innovations is supported by Stockmeyer and Weindlmaier (1999), who reported that 80% of 265 companies surveyed have launched at least one new product within recent 3 years. As a general tendency, in Germany the proportion of companies with product innovations tends to increase with the number of employees, however, in the ZEW surveys companies with 50–99 employees are a significant exclusion from this general tendency (ZEW, 2000, 2001). The relevance of food companies with process innovations decreased from 57% in 1998 to 40% in 1999 (Fig. 7). The proportion of companies which realise process innovations strongly increases with the number of employees: from 19% below 49 employees to 66% in companies with more than 200 employees (ZEW, 2001).

The company survey among 116 food SMEs carried out during the ERIS project between 1995 and 1997 (see Section 3.1) revealed that around 76% of them had innovation activities during last 3 years: 32.3% of them concentrated on product innovations, 40.3% spent more than 50% of their innovation budget on product innovations, while on the other hand 22.6% of the companies spent more than 75% for process innovations. This spread in the distribution of the innovation budget is a clear indication of the heterogeneous character of food SMEs in Germany. Their business strategies range from concentration to specific product niches (e.g. convenience-oriented products), the dis-

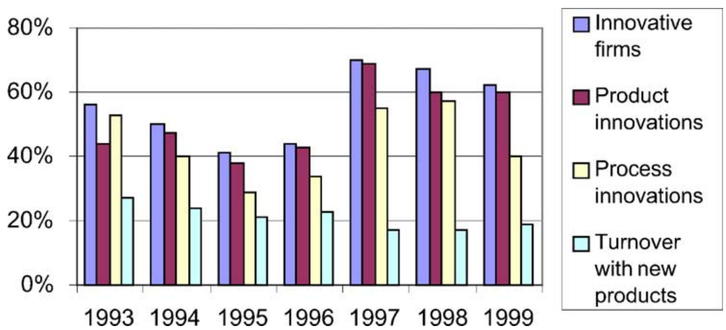

Fig. 7. Innovation activities in food industry companies 1993 to 1999. *Source*: ZEW (2001).

tribution in regional/local markets, the development of a service-oriented business strategy to the production of private labels at competitive costs (Menrad, 2002). However, empirical research indicates as well that many food SMEs have not yet focussed their businesses accordingly (Traill, 2000). Another characteristic feature of innovation activities in particular of SMEs in the food industry is the combined use of product and process innovations. In the company survey during the ERIS project, around two thirds of the innovating companies used both types of innovation in last 3 years. Similar results are reported from other surveys (ZEW, 2001, 2000).

According to the ERIS survey, the main targets of product innovations of food SMEs are focused on market and demand-oriented issues. This relates to a better penetration of new products in existing markets, to the opening of new markets as well as the improvement of the image and the design of the products. Other targets of product innovations like, e.g. a longer life span or broader application areas are regarded as less relevant (Table 11). In addition, the results of the survey clearly underline that product innovations of food SMEs are focussed in application fields which are familiar to the companies. For this purpose, often existing products are improved and further developed (Table 11). According to the results of the ERIS survey, the companies regarded market analyses (91.7% of the respondents assessed this factor as "very relevant" or "relevant"), experiences with similar products or the production process (90.5%) and own R&D activities (72.6%) as most important prerequisites for successful product innovations. However, only around 24% of the companies regularly co-operated with market research institutes and 34% of them did not employ specific personnel for R&D activities.

The targets for process innovations of food SMEs are wide-ranging, without a specific focus on a particular area. Besides the improvement of product quality (which was assessed as the most important target), cost-saving aspects (e.g. decrease of production costs, reduction of material/energy use), higher flexibility and faster production processes as well as improvement of the working conditions for employees were regarded as major targets by the respondents of the ERIS survey (Table 11). In addition, the results of this survey indicate that the companies mentioned modifications in the organisation of working processes (82.3% of the respondents assessed this factor as "very relevant" or "relevant") and training of employees (78.5%) as

Table 11
Targets of product and process innovations in food SMEs in Germany 1995–1997 (in % of the respondents)

Target	Very relevant	Relevant	Not relevant
Product innovations			
Environmentally friendly products	31.0	26.2	42.9
Broader application area	26.5	27.7	45.8
New design	49.4	32.5	18.1
Improved image of the product	45.2	46.4	8.3
Longer life span of the product	22.9	19.3	57.8
Improved performance	36.1	30.1	33.7
Development of new products in traditional fields	51.7	26.4	21.8
Development of new products outside traditional fields	7.0	19.8	73.3
Further development of existing products	39.1	44.8	16.1
Opening of new markets	58.6	33.3	8.0
Better penetration of products in existing markets	56.3	40.2	3.4
Process innovations			
Reduction of environmental pollution	39.2	27.8	32.9
Increase in production flexibility	44.3	34.2	21.5
Shortening of the length of a production cycle	34.2	34.2	31.6
Decrease of production costs	51.9	27.8	20.3
Improvement of product quality	74.7	21.5	3.8
Reduction of material/energy use	46.8	39.2	13.9
Improvement of working conditions of employees	40.5	40.5	19.0

Source: Own calculations based on ERIS survey.

most important prerequisites for successful process innovations, while technical aspects (like, e.g. purchase of licences or technical equipment) were regarded as less relevant.

According to the survey results of ZEW from 1997 to 1999, 17–19% of the turnover of the companies was achieved with products which were introduced in recent 3 years (Fig. 7). Teuscher (2000) estimated the proportion of product innovations of the last 3 years to 13% of the total turnover of three branches of the food industry in Mecklenburg-Vorpommern. For the Spanish food industry around 70% of the companies reported in a survey that new products launched between 1993 and 1995 accounted for less than 25% of total turnover (Martinez and Briz, 2000).

The high relevance of product innovations as well as the combined nature of product and process innovation which is characteristic in the food industry in Germany was registered in other EU countries as well. Martinez and Briz (2000) found for the Spanish food industry that almost 75% of the 54 companies surveyed introduced combined product-process innovations. In a survey among European food-manufacturing firms in 1996/1997, strong evidence was found that R&D expenditures were closely correlated with the development of new products (Traill and Meulenberg, 2002). In the PACE study which analysed the innovation strategies of the largest industrial firms in Europe, product innovations were also considered more important than process innovations in the food industry (Arundel et al., 1995).

Given the high numbers of product and process innovations, several studies have shown that radical innovations are very rare in the food industry. Most innovations in the food industry can be characterised as incremental innovations or even imitations (Grunert et al., 1997). According to a study by A.C. Nielsen, only 3.7% of the new products which were introduced in 1996 and 1997 in the German food market were assessed as “innovative”, while 80% were regarded as me-too products (Behr’s Verlag, 2002). Similar results were found in a study of the University of Göttingen, in which only 3% of the product innovations in the German food industry were described as “truly innovative” (Mehler, 1997), and were also reported for the US and the Spanish food industry (Gallo, 1995; Connor and Schiek, 1996; Martinez and Briz, 2000).

Galizzi and Venturini (1996) attribute the incremental nature of food product innovations to constraints on the demand side: European consumers tend to be conservative in their food choices and may initially reject new products. Therefore, fundamentally radical innovations are a high risk for food manufacturing companies. In this context, Padberg and Westgren (1979) introduced the term of “redundant technologies”, suggesting that technological opportunities in a specific area are often more advanced than the consumer’s willingness to accept new products. Since changing consumer taste and requirements have become the main drivers for the expansion of the EU food industry (Christensen et al., 1996), companies mainly react by introducing new food products whose characteristics are generally only incrementally different from existing ones.

5. Interaction between the different actors

The description of the innovation activities of the food industry in Germany has shown that this industry is particularly focused on market possibilities and the needs of end-users. However, at least part of the companies still show severe shortcomings in this respect. In addition, new scientific approaches and techniques are gaining increasing relevance for new product development in the food industry (see Section 3.2). Empirical research has further stressed the important contribution of supplying industries for innovation activities of food industry companies showing that the food industry benefits from technical developments in core technology fields (like, e.g. biotechnology, microelectronics, computer technology) through a well-developed network of interindustry purchases and sales of equipment and materials (Marengo and Sterlacchini, 1990; Klevorick et al., 1995; Rama, 1996; Christensen et al., 1996; Martinez and Briz, 2000). Many companies of the food industry acquire knowledge by purchasing new equipment or machinery (Christensen et al., 1996; Martinez and Briz, 2000; Traill and Meulenberg, 2002), as well as using new food ingredients developed by the supplying industries (Galizzi and Venturini, 1996). Therefore, the interactions between food industry companies, the supplying industries, end-users (both food retail companies and individual consumers) as well as research institutions play a crucial role for successful innovation activities.

Empirical results of analyses of co-operations of food companies show that generally domestic partners are preferred as partners in innovation projects. This relates in particular to Germany which had the smallest share of firms collaborating with foreign partners in a study analysing the innovation activities of the EU food industry. In this study, 29% of the German food companies surveyed co-operated with other companies in Germany, 10% with foreign companies, 44% with public institutions in Germany and 5% with foreign public institutions (Christensen et al., 1996).

The co-operation activities of 116 food SMEs in Germany have been investigated in a survey (in the context of the ERIS project[7]) between 1995 and 1997. As shown in Table 12, around 46% of these companies had co-operations with customers or the supplying industries. Informal contacts were the most frequent form of co-operations, while more formal ways were less frequently used. Interestingly, the companies surveyed gave higher relevance to the inclusion of supplying industry companies (74%) in innovation projects than to customers (48%). The inclusion of both types of institutions in pilot-use studies was even regarded as less relevant (Table 12). Co-operations with other companies (e.g. of the food industry) and research institutions were less frequently used than those with customers or suppliers. Around 26% of the food SMEs co-operated with other companies (Table 12) mainly by informal contacts. Around 28% of the surveyed food SMEs had co-operations with research institutions. In this context joint R&D projects (often in form of a Ph.D. or diploma thesis) and the use of laboratories or scientific equipment were regarded as most important form of co-operation while research contracts given to scientific institutions were assessed more critically (Table 12).

The estimations found in the ERIS survey are supported by the results of a survey among 265 food companies in 1998 in Germany. This study showed that co-operations with external institutions in product development projects take place “to a very low extent” (Stockmeyer and Weindlmaier, 1999). Mainly suppliers (of machinery and ingredients), at a low level also retail companies and market research institutes, were incorporated in innovation activities. Other partners like universities, other companies, consultants or consumers were hardly included, although in particular the inclusion of customers (e.g. retail companies, restaurants, consumers), research institutions and market research institutes had significant positive correlations with the success of the innovation projects (Stockmeyer and Weindlmaier, 1999).

The results of both surveys clearly indicate that at least part of the food companies in Germany have substantial shortcomings in the interaction in particular with end-users and customers in innovation projects, although the companies stress the high relevance of market issues and consumer needs in particular for product innovations (Table 11). The same relates to the co-operation with market research institutes, since only 26% of the food SMEs surveyed in the ERIS project regularly co-operated with such institutes although market analyses were regarded as most important success factor for product innovations. In addition, only a small part of the innovating food SMEs co-operated with research institutions. Often companies fear that details of the innovation project are published or research results are transferred to competitors or other institutions.

Another possibility to analyse the co-operations between different institutions is a look at the outcome of such activities. This relates in particular to scientifically-oriented research projects which often result in joint publications. Therefore, the partnership between industry and other institutions in selected field of food and nutrition-related research in Germany was analysed for the years 1990–992 and 1999–2001 using a bibliometric approach.[8] For this purpose, two areas of research were selected which represent traditional strengths of German institutions (cereals/starch/sugar and meat/fish), but showed declining numbers of publications in the last decade (see Section 3.2). In addition, two growing research areas were analysed which are characterised by the need of interdisciplinary co-operations: health and

[7] For details, see Section 3.1.

[8] The analysis was performed on the basis of the SCI database of STN (for details, see Section 3.2). In a first step, the industrial actors located in Germany were selected out of a list of all institutions which participated in the scientific publications of the selected areas. Afterwards all institutions located in Germany and abroad were selected which have been involved in publications with participation of industrial companies.

Table 12
Co-operations of food SMEs in Germany 1995–1997

Institution	Customer (%)	Supplying industries (%)	Other companies (%)	Research institutions (%)
Relevance of co-operations[a]	46.6	45.7	25.9	28.4
Form of co-operation[b]				
Informal contacts	88.9	88.7	90.0	n.a.
Exchange of experiences	53.7	47.2	66.7	n.a.
Inclusion in innovation projects	48.1	73.6	n.a.	n.a.
Pilot use studies	37.0	41.5	n.a.	n.a.
Use of laboratories/equipment	n.a.	n.a.	40.0	63.6
Joint R&D projects	n.a.	n.a.	26.6	60.6
Contract research	n.a.	n.a.	n.a.	36.4
Joint PhD/diploma theses	n.a.	n.a.	n.a.	60.6

n.a.: the respective form of co-operation was not asked for this institution in the survey. *Source*: Own calculations based on ERIS survey.
[a] The proportion of all surveyed companies have co-operations with the different types of institutions.
[b] The percentage of those companies with co-operations with the relevant type of institution assessed the different forms of co-operations as "very relevant" or "relevant".

nutrition as well as food structure (including quality improvement of food and new ingredients). However, both areas were underproportionately represented in Germany compared to the EU or global average (see Section 3.2).

The results of the bibliometric analyses for the "traditional" fields of cereals/starch/sugar as well as meat/fish are shown in Table 13 and the dynamically growing areas of health and nutrition as well as food structure in Table 14. Some general trends can be filtered out from these analyses:

- All selected fields showed an overproportional participation of industry companies in scientific publications compared to the overall average of the German industry which accounted for 5.4% of all SCI publications of German institutions (Schmoch, 2001).
- In comparison to food and nutrition research in total in which around 12% of all German SCI publications came from industry companies (Schmoch, 2001), only the area of cereals/starch/sugar showed a continuously overproportional participation of industry companies while in the other fields at least in one time period an industry proportion below average was registered.
- The average number of partners per publication significantly increased in all selected fields during the last decade.
- The partnerships in three of the selected fields were dominated by co-operations among industry companies. Intensive co-operations between industry companies and domestic and foreign research institutions were observed only in the field of nutrition and health.
- The relevance of large companies decreased in all areas between 1990/1992 and 1999/2001. In contrast, the proportion of SMEs and domestic research institutions increased in most areas.
- Among the research institutions located in Germany mainly university institutes co-operated with industry companies, while other research institutions seemed to be of minor relevance.
- There is a tendency towards internationalisation of the co-operation activities in the selected fields.

In the area of cereals/starch/sugar the number of publications with industry participation remained stable between 1990/1992 and 1999/2001. Due to the decrease in the total number of publications, the respective proportion increased from 22% of all publications at the beginning of the decade to 27% at the end (Table 14). Large companies mainly of the food industry and food suppliers (e.g. machinery, equipment, producers of ingredients) were the most important group among the authors, followed by SMEs and domestic research institutions which both gained relevance during the 1990s. Despite the fact that one federal research centre is active in the field of cereals, starch and sugar research (see Section 3.1), this type of institution had only minor relevance in co-operations with

Table 13
Co-operation in scientific publications in the fields of cereals, starch and sugar as well as meat and fish

Type of institution	Cereals, starch, sugar		Meat, fish	
	1990/1992	1999/2001	1990/1992	1999/2001
Large companies (total)	64.0%	43.0%	22.5%	18.3%
Food industry	31.0%	28.2%	1.1%	–
Pharmaceutical/health	22.0%	3.4%	10.2%	4.2%
Food suppliers	11.0%	11.4%	11.2%	14.1%
Small and medium enterprises	19.0%	24.1%	48.9%	40.8%
Industry associations	3.0%	6.7%	20.5%	5.6%
Research institutions	14.0%	23.4%	6.8%	15.5%
Private institutes	1.0%	6.7%	-	-
Federal research centres	4.0%	2.0%	1.1%	4.2%
Max Planck institutes	–	1.3%	–	–
Leibniz institutes	–	–	–	–
Universities/technical colleges	9.0%	13.4%	5.7%	11.3%
Institutions outside Germany	–	2.7%	1.1%	19.7%
Number of institutions	100	149	88	71
Number of publications	75	76	79	33
Proportion of all publications	22.2%	27.5%	16.5%	8.5%
Average partner/publication	1.3	2.0	1.1	2.2

Source: Own investigations.

industry companies. The co-operations in this field were dominated by German institutions since only a very small proportion of the authors came from foreign countries.

The number of publications with industry participation as well as their proportion among all publications was halved in the area of meat/fish during the last decade (Table 13). In both time periods, SMEs

Table 14
Co-operation in scientific publications in the fields of health and nutrition as well as food structure/new ingredients

Type of institution	Health and nutrition		Food structure	
	1990/1992	1999/2001	1990/1992	1999/2001
Large companies (total)	80.0%	31.5%	50.0%	29.3%
Food industry	–	0.9%	5.0%	–
Pharmaceutical/health	80.0%	27.9%	–	–
Food suppliers	–	2.7%	45.0%	29.3%
Small and medium enterprises	–	7.2%	5.0%	26.8%
Industry associations	–	–	5.0%	–
Research institutions	–	23.8%	20.0%	26.8%
Federal research centres	–	0.4%	–	–
Max Planck institutes	–	0.4%	–	–
Leibniz institutes	–	1.3%	–	–
Universities/technical colleges	–	14.0%	20.0%	26.8%
Clinics	–	7.7%	–	–
Institutions outside Germany	20.0%	37.4%	20.0%	17.0%
Number of institutions	5	222	20	41
Number of publications	3	66	11	16
Proportion of all publications	3.7%	13.2%	17.2%	7.2%
Average partner/publication	1.6	3.4	1.8	2.6

Source: Own investigations.

represented the predominant author group. At the end of the decade, foreign institutions, large companies (mainly suppliers of machinery and equipment) and domestic research institutions were equally strong partners in scientific publications. Compared to the beginning of the 1990s, in particular foreign research institutions and university institutes gained relevance in partnerships with industry companies. Like in the other "traditional" field, federal research centres do not seem to be preferred co-operation partners of industry, although a specific centre exists in the meat area as well (see Section 3.1).

In the area of health and nutrition, both the number of publications with industry participation as well as the respective proportion significantly increased during the 1990s (Table 14). In particular, large pharmaceutical or health-related industry companies were interested in this field, while food industry companies, food suppliers as well as SMEs were less frequently involved in the partnerships. In general, the pharmaceutical companies co-operated with several research institutions (including clinics) as indicated by the high average number of authors in this field. The majority of these research institutions came from foreign countries, which represented the biggest group of authors (Table 14). Research institutions from outside Germany seem to fulfil the requirements of (pharmaceutical) industry companies to a higher extent than German institutions. The findings of this bibliometric analysis clearly underline the structural deficits of the innovation system at the borderline of food, nutrition and health in Germany (Menrad, 2001).

The proportion of articles with industry participation significantly decreased in the field of food structure in the 1990s in Germany (Table 14). In the partnerships, there was a clear shift observable from large companies (mainly producers of food ingredients) to SME during the decade, while the relevance of research institutions both located in Germany and abroad remained stable during this time period. Among the research institutions in Germany, all authors in SCI publications came from university institutes in both time periods, although scientists from Leibniz institutes and federal research centres have been involved in relevant research projects organised and financed by FEI (FEI, 2001), but these projects do not seem to result in publications in reviewed journals covered by SCI.

6. Political and legal framework conditions

Due to the increasing internationalisation of the food markets, political aspects are becoming more and more important for the food industry. In this context, the relevance of international agreements and regulation is increasing as well. In particular, the recommendations of the Codex Alimentarius Commission with its 165 member states plays a central role, since an increasing number of countries transfers these standards into national regulations. In 2000, the Codex Alimentarius contains more than 200 food-related standards, around 3000 upper limits for pesticide residues and more than 1000 assessments of food additives.

There are no specific regulations or funding programmes which intend to directly support innovation activities of the EU or German food industry. The financing of R&D projects in the field of food and nutrition (analysed in Section 3.3) has supporting character for innovations. The innovation activities of industrial companies are further influenced by those regulations which regulate the market entrance of companies, the launching of new products, processes or services as well as influence consumer demand related to innovative products. In this context, regulations for food safety, for the use of specific technologies or ingredients as well as labelling requirements are of particular relevance for the food area. In addition, there are additional regulations for the market introduction of specific types of food (e.g. novel food, dietetic food).

At the beginning of the year 2000, the Commission of the EU published a White Book on food safety in which the creation of an independent European Food Authority (EFA) was suggested. EFA should give scientific advice to the EU in all areas related to food safety, but will not have any regulatory competencies. Following the BSE crisis the institutional framework of consumer protection in the food area was reorganised in Germany as well. In analogy to the EU, a politically and economically independent Federal Institute for Risk Assessment was established at the beginning of 2002 which shall identify and assess health-related risks of food and make suggestions for risk management (BMVEL, 2002).

As a general principle the production and market introduction of new food products is not limited in Germany as long as these products do not harm the health of consumers or try to mislead them. This general principle is limited, e.g. for novel food which require a specific permission for market approval by the competent authorities. This does not only relate to food products which consist of genetically modified organisms or are produced with the help of them, but also to some types of functional food (Menrad, 2001).

7. Food demand

The development of food demand in Germany is characterised by relatively low growth rates which are often below the general price increase of the overall consumption of private households. As shown in Table 15, in particular the turnover of food retailing showed low growth rates in the last decade while the market volume of food consumption outside the private household (e.g. in restaurants, canteens, snack bars) developed much more dynamically. In 1999, the turnover of food retailers amounted to around 223 billion DM in Germany (Table 15). In total, consumers spent more than 333 billion DM on sales of food, beverages and tobacco, and additionally 178 billion DM on meals and beverages outside the own household (Table 15). In contrast to food retailing shop, a broad variety of additional distribution channels are gaining increasing relevance for the purchase of food. This relates, e.g. to direct sales of farms (with an estimated volume of around 6 billion DM per year), sales in petrol stations, small kiosks, with the help of vending machines or food delivery services. However, the food sales via Internet are still on a very low level in Germany: they were estimated to around 400 million DM in 2000 (Menrad, 2002).

Due to the saturation tendencies on the food market in Germany, the percentage of consumer expenditures which are spent for food purchases significantly decreased in the last decade. While in 1990, 21.9% of the overall consumption of consumers was spent on food, this percentage decreased to 14.9% in 1999 (BMELF, 2000). In addition, there is a tendency of individualisation and polarisation in the food market in Germany in which the middle price segments significantly lose relevance. Consumers in Germany are rather price sensitive with regard to “basic food”. This behaviour has much lower relevance in product segments which offer specific benefits to consumers (e.g. convenience-oriented food, health-related food, food from organic farming, ethnic food). Another important trend is a strong emphasis on quality aspects, taste and freshness of food as well as high consumer sensitivity regarding the quality and origin of raw materials, additives and technologies used in food processing, as well as all aspects of food safety (Menrad, 2002). Despite the general saturation tendencies on the German food market, there are some segments which show interesting growth perspectives for the future. This relates, e.g. to convenience products, health-oriented food as well as food from organic farming. Therefore, many companies of the food industry regard these fields as “strategic business areas” and organise their innovation activities accordingly: 19% of all product innovations introduced in the German food market between 1999 and 2001 were targeted to functional food and an additional 18% to convenience-oriented products (Datamonitor, 2001).

During the recent decade rapid and extensive concentration took place within the German food retail trade. In 2000, the five largest German food retail companies had a market share of 62% (Deutscher Fachverlag, 2001) which is expected to increase in the coming years. The market power of food retail companies increased as a consequence of this concentration process. Due to limited sales, shelf and refrigerating capacities, food retailers are more and more getting the role of a gate keeper for new products who decides which product innovations will be listed in his assortment. In addition to intensive promotional activities

Table 15
Expenditures of consumers for food (in billion DM) in Germany

Segment	1991	1995	1997	1999	Growth rates (%)
Turnover of food retailers	207.0	218.0	220.7	223.2	7.8
Consumer expenditures for food, beverages and tobacco	302.8[a]	314.7	321.5	333.1	10.0
Meals outside the private households	136.0	161.0	168.0	178.0	30.9

Source: Deutscher Fachverlag (2001), BMELF (2000) and Frohn (2000).
[a] Figures for 1992.

for newly launched products and paying of listing fees, most food retailers expect that a food company presenting a new product for listing has to name another product which will be replaced by the new one. In addition, most of the large food retail companies in Germany regard the sales price as a strategic instrument in competition and try to transmit price reductions to the supplying companies of the food industry. This is an increasingly difficult situation for SMEs of the food industry which do not have strong brands.

8. Conclusions

In recent years, the focus of the innovation activities of the food industry in Germany has shifted from being an industry, which strongly depends on technological developments in the supplying industries, towards being a demand-focused product-oriented industry which launches a high number of new or modified food products, often combined with process innovations. This reorientation of the food industry is underlined in company surveys in which market and demand aspects are identified as most important prerequisites for successful innovations. However, there are still significant implementation deficits, in particular in SMEs which involve e.g. market research institutes or customers to a low percentage in their innovation activities. In this respect, there is a high potential for improvement in the coming years which should be used by the companies of the food industry.

In the coming years, the food industry will be confronted with a broad range of new scientific approaches and technological opportunities. Besides modern biotechnology and functional food this relates in particular to information and communication technologies, process-automisation, new food processing and packaging techniques (e.g. high pressure technology, sous-vide technique, modified atmosphere packaging, aseptic packaging), of which the scientific principles have been developed in the last decade, but only parts of them have been implemented in food industry companies so far (Menrad, 2001). However, the analysis of the innovation activities of food industry companies in Germany indicate that in particular SMEs of the food industry do not fulfil the necessary prerequisites to integrate complex new technologies in the existing processes or to develop new products using such technologies. Thus, developing competencies to interface with these technological opportunities will be one of the most important tasks for many companies of the German food industries in the coming years. This task cannot be realised successfully without a certain extent of in-house capacity for R&D activities. This implies for the food industry, that the existing technological opportunities cannot be used optimally without at least a step-by-step extension of the R&D budgets in the coming years.

The establishment of external knowledge and competence networks will be another priority task in particular for many SMEs of the food industry in future. If co-operations are carried out, most SMEs co-operate with supplying industries so far. In future, there seems a strong necessity to expand the knowledge base of external co-operations of SMEs significantly (e.g. customers, research institutions, specialised service providers, other companies of the food industry), since most SMEs only can overcome their inherent limitations during the innovation process with intensified co-operation activities. In this sense the food industry seems to be moving towards the network-oriented management systems and practices which are often applied in high-tech industries (e.g. biotechnology, information and communication technologies) in the coming years. In addition, strategic partnerships with other companies are a key element for the enlargement of the supply of many SMEs of the food industry as well.

There is a broad and differentiated knowledge base for research activities with relevance for the food industry in Germany. Weak points in the process of knowledge generation are a spatial and factual fragmentation of the research institutions, a traditionally oriented research focus of many institutes, deficits in interdisciplinary co-operation as well as lack of the necessary structural, instrumental and partly personnel conditions to implement modern scientific approaches and methods. In addition, new methodologies and techniques are often not incorporated in the education of students.

There are strong differences between the different types of research institutions active in the field of food and nutrition concerning their willingness to co-operate with industrial partners and to commercialise the generated knowledge. The co-operation analysis reveals that mainly university institutes are interested in industrial co-operation, while other organisations (in particular federal research centres, Helmholtz centres) are not very active in this respect. Even though these organisations have other primary targets, this implies that part of the generated knowledge will be used suboptimally, assuming that a certain extent of tacit knowledge is relevant for new scientific approaches and technologies.

In the coming years, a significant extension of the public funding budgets in the field of food and nutrition research seems hardly realistic, due to the financial restrictions in public households in Germany and demands from other fields of science and technology. However, the analysis carried out reveals a strong fragmentation and low co-ordination of the activities of the funding organisations involved. Therefore, an intensified co-ordination of the activities and initiatives of the different funding organisations seems to be necessary in future in order to increase efficiency in research funding. Furthermore, the single funding organisations should focus their activities on strategic fields in order to be able to provide a critical mass of research funds. The main focus and the procedures of research funding of the different organisations should be evaluated periodically in order to ensure flexibility. External know-how (e.g. foreign scientists) should be involved in these evaluation processes. Increased flexibility in research funding in the field of food and nutrition also could be achieved by expanding the proportion of project-oriented programmes, since significant parts of the research funds in this field are devoted to institutional funding. With an adequate shaping of the funding conditions of project-oriented research programmes it is also possible to stimulate co-operations between companies and research institutions, since the till now institutionally funded organisations show a relatively low interest in co-operation with industry.

The political and regulatory framework conditions often do not keep up with scientific and technical developments in a lot of innovation fields relevant for the food industry. In particular for regulations which need to come to an agreement on an international level this often results in a phase of regulatory uncertainty which hinders innovations. Such developments take place both in fields in which consumers or users are rather critically concerning the use of a specific technique (e.g. genetic engineering or food irradiation), but also in fields in which consumers have a positive view of innovative products (e.g. functional food). In this sense there is strong need for action in order to clarify, harmonise and state the relevant regulations more precisely in the coming years.

In particular, in innovation fields of the food industry, which need a strong multidisciplinary co-operation, the institutional framework conditions and administrative competencies often hinder innovation activities since several administrations with differing decision criteria and procedures are responsible for the implementation, management and control of existing regulations. In this sense, scientific and technical innovations necessitate institutional change which frequently follows with significant time delays at least in the administrative bodies responsible for the food industry in Germany. Therefore, a more flexible framework for regulations should be created for newly emerging innovation fields which can be jointly formed by public authorities and early innovators.

The creation of interfacing competencies in food industry companies (in particular, SMEs) seems to be one of the most relevant tasks for successful innovation activities in future. Therefore, national and international policies should not solely concentrate on stimulating knowledge generation with relevance for the food industry but should have the additional target to support advances of the knowledge base of the food industry companies themselves. Only if the prerequisites for successful co-operations with other actors of the innovation system and the diffusion of complex scientific approaches and technologies into SMEs of the food industry can be created more successfully than in the past, this group of companies seems to be sufficiently prepared for future challenges. Since their ability to integrate existing or new knowledge in their own innovation activities mainly increases by “incremental learning”, one main area of political activities should be the support of joint projects of industry companies and research institutions in selected fields which either have a high future potential or cover specific needs of SMEs. In addition, it seems necessary to direct the activities of transfer institutions to growing fields in food and nutrition research to a higher extent than in the past. All in all, political activities should be stronger targeted to the diffusion of new scientific approaches and technologies in the food industry than exclusively on the support of knowledge generation.

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