Reversed Food Chain – From the Plate to the Farm

Priorities in Food Safety and Food Technology for European Research

Oliver Wolf
Hans Nilsagard

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Foreword

The production, processing and retailing of food has changed throughout the last century from local structures into a global production and logistic system. This development, together with technological progress, led to increased complexity in the European food sector. New business opportunities arose for food producers, while at the same time the safety of food production had to comply to higher standards.

Today, research and technology play a decisive role for the European food sector for the development of new products as well as for improved safety measures. In July 2000, DG RTD requested a study on potential future European research priorities in food technology and food safety from the Institute for Prospective Technological Studies (IPTS), Joint Research Centre. The study design comprised the involvement of external expertise from industry as well as from academia: The results of the study were derived from two experts workshops held in Sevilla at the IPTS in December 2000 and May 2001.

The experts ideas and concepts were complemented with additional information generated by the European Science and Technology Observatory (ESTO). The report "IPTS/ESTO Prospective study on food technology and safety" which gave input into the expert workshops as well as into this report was carried out by A. Braun (VDI-TZ, Germany), M. Leonardi (ENEA, Italy), N. H. Kristensen (Technical University of Denmark), T. Adamidis/E. Tsakalidou (ATLANTIS Consulting, Greece) and W. Van Aerschot (VITO, Belgium).

The co-ordination of the study as well as the present synthesis report were done by Oliver Wolf and Hans Nilsagård, IPTS. Whilst IPTS is grateful for the help and inputs received from other European Commission services, the participating experts and the ESTO network, responsibility for the content rests solely with the IPTS.

Seville, September 2002 Per Sørup

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Executive Summary

Background

The benefits and risks inherent to food technology and food safety in Europe have brought these topics to the centre of public interest in the recent years. The challenge for the future is to maintain the food sector competitive and innovative at a global level, while increasing the safety of production processes along the food chain. Therefore research priorities have to be developed at the European level which integrate these requirements into a long term perspective.

The objective of this study is to identify precise and manageable research priorities, which strengthen specific areas in the food sector. For this purpose, a group of high level experts met for two workshops in Seville, Spain. They identified the most important areas for the future of the European food sector and derived from this a series of research priorities for European food safety and food technology.

Findings

The overriding outcome of the entire research activity is the need to focus on the end consumer as the most important element in the food chain, and to re-construct the single elements of the food production and distribution process from the consumers perspective – in other words to start a reversed food chain thinking. This approach makes it possible to come to a kind of hierarchical analysis of the research issues in three main categories[1]:

Consumer Science

Consumer confidence in food safety has recently dropped to very low levels, as illustrated e.g. by the public debate on genetically modified food and the effects on the market of recent food scandals such as the BSE crisis or the contamination of chicken with dioxin. Confidence has to be re-established, and for this to happen new food process and product developments have to include consumer participation/representation from the beginning. The priorities for future research have been split into those issue relevant for the "Consumer behaviour under normal circumstances" and the "Impact of food crises on consumer behaviour":

Food Safety and Health

Re-establishing consumer trust relies essentialy on increased efforts in food safety and health. One part of the identified research priorities therefore focuses on measures to increase safety in the entire food chain. Other priorities address the need to identify indicators for a "disease profile" of the European population in order to guide the development of functional food with enhanced health characteristics.

Basic Food Science

The main rationale underlying the "Basic Food Science" priorities is the need for increased understanding of the functionality of food material and its

[1] The individual priorities are listed at the end of this Executive Summary.

interaction with the human metabolism. Knowledge gained from these research issues is the essential basis to facilitate research as described in the priorities for “Food Safety and Health”.

Conclusions

This study combines the discussions of the main impacts on the European food sector (food crises, technology progress, globalisation) with a forward looking exercise. As a result, key categories for future research in the European food sector are outlined, and potential research priorities are defined.

The distrust of consumers towards policy makers and food industry in the wake of several severe food scandals obviously had a strong influence on scientists and experts linked to the present study. This influence led to the overriding outcome to re-establish consumer trust through analysing all research priorities in the light of consumer perception and consumer behaviour. This idea developed into the concept “The Reversed Food Chain – From the Plate to the Farm”.

From an economic point of view, this development corresponds to experiences already achieved in other markets – the shift from supply-driven markets to demand-driven markets. As food is one of the basic goods, this means that once a basic level of food supply is guaranteed, the consumer develops an increased interest in quality and variety. Through the ability to choose between a broad range of food products, the consumer acceptance of new food is the final criterion for a successful market introduction. Accordingly it will be necessary in the future to take the consumers point of view at every stage of food product development, processing and marketing into account.

From this point of view, the recent food crises were only the trigger to show that the consumer behaviour, satisfaction, acceptance and trust in products and producers, are the decisive factors in the food market. Therefore the concept of the “Reversed food chain thinking – from the plate to the farm” is not a hasty reaction to food crises, but the consequent response to a long-term development in the food market.

List of Research Priorities

The research priorities are listed in the following tables according to the three main categories “Consumer Science”, “Food Safety and Health” and “Basic Food Science”. The priorities have a continuous numbering (P1 – P33) across all categories in order to ease the identification and cross-references.

Table 1: Research priorities in the area of consumer sciences

CONSUMER SCIENCE

Consumer behaviour under normal circumstances

P1 Determinants of perception of healthiness based on communication and physical product characteristics
P2 Foods designed for special interest groups meeting nutritional, sensory and functional requirements
P3 Labelling
– Labels as credibility signal
– Communication in credibility alliances
– Design of labels based on behavioural science
P4 Traceability from a consumer viewpoint
– Consumer information demand
– Trust
– Differentiation and Segregation
P5 New purchase patterns, information technology and health and safety
P6 Life style and calorie management in the diet
P7 Consumer willingness to pay for increased quality and healthiness
P8 Consumer perception of new food technologies

Impact of food crises on consumer behaviour

P9 Risk perception, information demand and communication in a crisis situation
P10 Analysis of amplification of food crises
P11 Food crisis containment

Table 2: Research priorities in the area of food safety and health

FOOD SAFETY AND HEALTH	
P12	Immunological system/Bacterial interaction in the colon
P13	Bioefficacy understanding - advanced techniques for molecular monitoring
P14	European consolidated epidemiological information, recommendations and priorities
P15	Identify consumer priorities (wishes) for safety & health and develop solution strategies validated by scientific experts
P16	Establish HACCP equivalent methodology for risk assessment to maximise upstream prevention
P17	Develop anticipatory/predictive risk methodology with two main objectives: - Priorities development - Preparation of competences and analytical methodology
P18	Availability of healthy food - Resolve technological hurdles: - Low sensory quality of desirable ingredients - High cost - Maintain calorie management: Bulk & Satiety
P19	On-line monitoring techniques, based on molecular tracing: Metabolic risk factors or desirable raw ingredient components (Bioactive molecules)
P20	Investigate Animal – Man/Plant – Man Transferability

Table 3: Research priorities in the area of basic food science

BASIC FOOD SCIENCE

Safer Production Methods

P21 Development of safer production methods for animal feed
P22 Risk management of new and existing technologies (allergens, emerging pathogens)
P23 Up-dating of hygienic technologies and preservation technologies
P24 Understanding interactions of food (ingredients) and processing at the molecular and cellular level
P25 Benefits and risk assessment of new raw materials

Impact of Food on Health

P26 Gentle processing – generating and maintaining health-promoting quality
P27 Improvement of health generating properties of new food raw materials
P28 Process design, product design, and information technology
P29 Balancing microbiological flora for health promotion – immunostimulation

Analysis/Detection of Contaminants and Pathogens

P30 Sensor development (rapid, non-invasive) for detection and analysis/identification of allergens, food contaminants, pathogens, prions, foreign matter, hormones
P31 Detection of non-intentional horizontal genetic material transfer

Traceability

P32 Tools and procedures for traceability

Environmental Health Risks

P33 Understanding the development of allergens - activation/generation

1. Introduction

1.1 Objectives of the report

This report is the result of a joint activity of DG RTD and DG JRC-IPTS, which was launched in July 2000. The aim was to identify potential priorities for future research areas in European food technology and food safety. This should provide targeted information for decision-makers in DG Research in order to set the appropriate priorities for future research programmes. The main focus was initially set on advanced technology developments in the food sector and on socio-economic factors, which are expected to have an impact on the food producing industry. Due to developments in the food sector late 2000 beginning 2001, the focus changed slightly during the progress of the activity towards food safety and health issues. However, the main objectives remained unchanged, amongst them the need to define research issues which stimulate innovation in order to foster competitiveness in the European food sector.

Although the prospective character of the activity and the request to think in new directions required an open-minded look at the food sector, some elements of the "real-world" configuration had to be taken into account from the beginning. This was in particular the regulatory system within the European Union, and here especially the EC White Paper on Food Safety[2] from 1999, which already contains a strong notion of food safety and health. Also the directives on labelling and the release of genetically modified organisms played a role in the development of future research issues. Additionally, the new framework programme FP6 as well as the concept for the European Research Area ERA were under development at that time, and the preparations for the European Food Agency EFSA were on the way. All these factors, most of them in the state of flux, had to be taken into account. They were however all dominated by the BSE crisis, which emerged at the end of 2000 and had a strong influence on the final outcomes of this activity.

1.2 The European food sector

The definition of research priorities for the European food sector will necessarily focus on the single stages of the food chain, from raw material production through post harvesting, processing, post-processing, and distribution to the end consumer. Therefore it's essential to have at the beginning an idea of the current state of the art of the sector and the main developments along the food chain at the moment.

During the next 10 years, the European food sector will continue its since long ongoing structural transition. The traditional situation, with local demand being met by independent farmers and food processors in the neighbourhood, has been replaced by a global market place where multinational groups are serving consumers in several countries. The trade flow with food products will continue to increase. Trade restrictions for agricultural products are continuously being reduced and the introduction of the European single

[2] White paper on Food Safety- COM(1999)719 final, European Commission

market and the common currency will further facilitate increased trade. The enlargement process will bring in new member states in the EU with large agricultural sectors, changing the European market for food products. Still for most countries, the domestic production is the base for the national food supply system, but the industry structure is changing.

At one end of the food chain, consumer demands shift according to demographic changes and economic development. New consumer segments are being defined while others are losing in importance. Traditionally, the most important segmentation of consumer groups has been defined on national levels. However, with incomes and socio-demographic characteristics converging, it seems likely that also consumer patterns will converge, leading to “trans-European” consumer segments. Nevertheless cultural differences between regions/nations will continue to influence consumer demand in the foreseeable future.

At the other end of the food chain agricultural practices are going to change. The increased focus on environmental sustainability in society is reflected in the rapid growth for organic agriculture, while the use of modern biotechnology might be offering many new opportunities for agriculture in the EU. The enlargement process and further reforms of the CAP could lead to a drastically changed market and production situation. With increased trade and more global media coverage, impact from food supply crises such as the BSE issue receives instant Europe-wide attention, creating consumer reactions not experienced before.

Between the consumer and the agricultural production, the food processing industry and the retailing sector tries to adjust to changed consumer demands and the opportunities and restrictions from the changes in agricultural sector. New techniques offer great opportunities for those who adapt them timely while others will be forced out of business due to the increased competition. The retailing sector is in the middle of a structural revolution. The introduction of very large supermarkets, where IT based logistics have dramatically increased labour productivity, brings immediate benefits to some consumers in the form of lower food prices. In front of us the next retailing revolution is visible in the form of internet based virtual shopping malls.

1.3 Rationale for EU financed research

Food technology and safety research financed by the European Commission has the obvious objective of *enhancing the quality of life*, in the short term as well as in a long-term perspective. Research as such is most often seen as a long-term activity and even the most applied research should be regarded as an investment for future benefits. Nevertheless, the EU should address research on short-term issues, in order to meet the needs of rapid and accurate information in cases of emerging transnational crises.

Food safety issues, as well as the use of technological breakthroughs leading to improved and cheaper products, are seldom isolated to one or a few nations. The EU Framework Programmes have the important role of breaking up national research boundaries making possible logical and well-organised structures, which at the end increase research efficiency. Especially in the context of food safety, research results represent the foundation for the

implementation of public policies, both on national level and the level of the European Union.

Strengthening the economic growth is another objective for supporting R&D in the European food sector. Thus, improving the European quality of life goes wider than only addressing the consumer. Research that fosters the competitiveness of the food industry in Europe creates the possibility for increased employment opportunities. This can be done through the development of new and improved products as well as production systems using new technologies. In many cases research aiming at consumer benefits will have the secondary effect of increasing competitiveness through the successful marketing of improved and cheaper products. Some issues of competitiveness may not however be addressed by development in products and production systems. An example could be the specific need for increased regional competitiveness through changed economic structures. These types of issues are not tackled in within the scope of the project.

In the long-term perspective, success in achieving both consumer benefits and increasing competitiveness depends on *the quality of basic research*. In often highly specialised areas, research co-operation between scientists in different member states is of utmost importance to achieve and maintain a high level of quality. Within EU research activities, the transnational nature of research should hence be dealt with by combining complementary expertise in different countries, also leading to increased research productivity through economies of scale.

1.4 Project structure

In order to identify future developments in European research in food technology and food safety, the IPTS invited a group of high level experts for two workshops, which took place in Seville in December 2000 and May 2001 (see fig. 1).

First workshop

In the first workshop, the experts pointed out thematic clusters for future research according to their opinion and experience. These clusters were defined in a guided brainstorming process. References to existing and past research programmes and initiatives were minimised to ensure a creative approach to the topic.

The resulting thematic landscape of research issues, which included a broad range of topics from e.g. functional food over the generation of new raw material to traceability and labelling systems, was subsequently checked for comprehensiveness and put into a logical order. A major output of the first workshop was the arrangement of the clusters according to *the reversed food chain thinking* (see chapter 2.1). An intermediate report was drafted which fed into the development of FP6, which was being carried out by DG Research in parallel with this project[3].

[3] Proposals for Council decisions concerning the specific programmes implementing the Framework Programme 2002-2006 of the European Community for research, technological

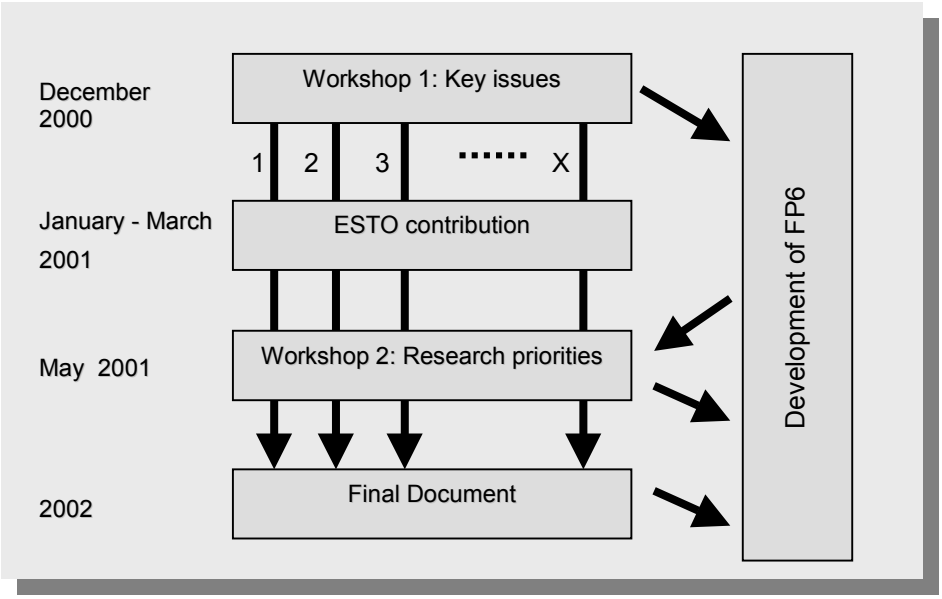

Figure 1: Structure of the overall activity and the interaction with the development of FP6 and ERA by DG RTD.

ESTO-contribution[4]

The analysis at this stage puts the results of the first workshop into a broader context and analysed additional questions, to be discussed at the second workshop. In particular:

- The results of workshop 1 were set into the current research context. Therefore, a brief background of the identified clusters was outlined.
- The single clusters in each particular research area were positioned in relation to each other. Available material (from publications or through contacts to experts) concerning each single cluster was collected and put into a suitable form which highlights their special relevance for their research area. The appearance of some of the clusters in FP5 and their relevance for FP6 (e.g. traceability systems) was highlighted.

development and demonstration activities/concerning the specific programmes implementing the Framework Programme 2002-2006 of the European Atomic Energy Community for research and training activities, http://europa.eu.int/comm/research/pdf/com-2001-279-en.pdf , pp.32-34.

[4] ESTO = European Science and Technology Observatory, a network of European research institutes under the guidance of the IPTS.

Additional tasks were:

- To bring the results from the first workshop in line with FP6 and the concept of the European Research Area ERA.
- To give an overview of the proposed profile of the European Food Agency EFA and indicate the need for adapting the results of the project.

Expert discussions during the first workshop at the IPTS in Sevilla

Second workshop

In the second workshop, the expert group revised the results of the first workshop and the ESTO intermediate report[5]. In addition, an outline of the structure of FP6 was presented by DG Research, which served as an overriding frame for the workshop discussions. The main aim was to evaluate the identified research issues and to assess them under the specific criteria, which had been developed in the frame of the ERA[6]:

- Why should the research area receive public funding? Can the issue be addressed better at the individual company level?
- Why is should this research area be supported at the European level and not in the frame of national programmes?
- What is the added value of this research area for the European citizen?

[5] The expert group in the two workshops were nearly identical in order to ensure continuity, see Annex .

[6] Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions – Making a Reality of The European Research Area: Guidelines for EU research activities (2002-2006), http://europa.eu.int/comm/research/area/com2000-612-en.pdf, p.9

The second workshop therefore was the most important element of the overall activity, as it finally led to a series of research priorities, which assist DG Research in formulating details of future research programmes.

Maurice Riboh (Danone), presenting results from the group discussions in the second workshop

1.5 Structure of the report

After this introductory chapter follows an outline of the project approach in chapter 2. The reversed food chain thinking is presented and the parallel development of the 6th Framework Program and ERA is brought into the analysis. Chapters 3 to 5 cover the resulting research priorities as developed in the project. Chapter 3 addresses consumer science, chapter 4 deals with issues in the area of food safety and health while chapter 5 focus on specific priorities in basic food science. A concluding remark in chapter 6 finishes this report.

2. Approach

2.1. The Reversed Food Chain Thinking

In order to generate a consistent structure, a working model for the research priorities was developed at an early stage of the project. The starting point for this working model was the last few years' public attention and debate on food safety issues, caused by several recent food supply incidents, e.g. the escalation of the BSE disease in various Member States. These food crises are considered by EU consumers not only to be a failure of the regulatory system, but more importantly, they considered as a failure of science. As a result, general food safety and environmental concerns were exacerbated in the EU in the aftermath of the BSE crisis. These public concerns extend to areas as diverse as GMOs (Genetically Modified Organisms), the use of antibiotics in animal feed, and the use of hormones as growth promoters in animals. To regain the public confidence a new approach is needed when analysing and proposing future research priorities in food technology and food safety. By clustering relevant research areas and identifying the underlying rationale for each cluster it becomes clear that the consumer role should be in focus. Therefor the basic concept proposed here is a re-construction of the food chain from the consumer point of view, *the reversed food chain thinking*. This reconstruction of the food chain from the consumer perspective served in the following as the reference system for the development and grouping of the single research priorities.

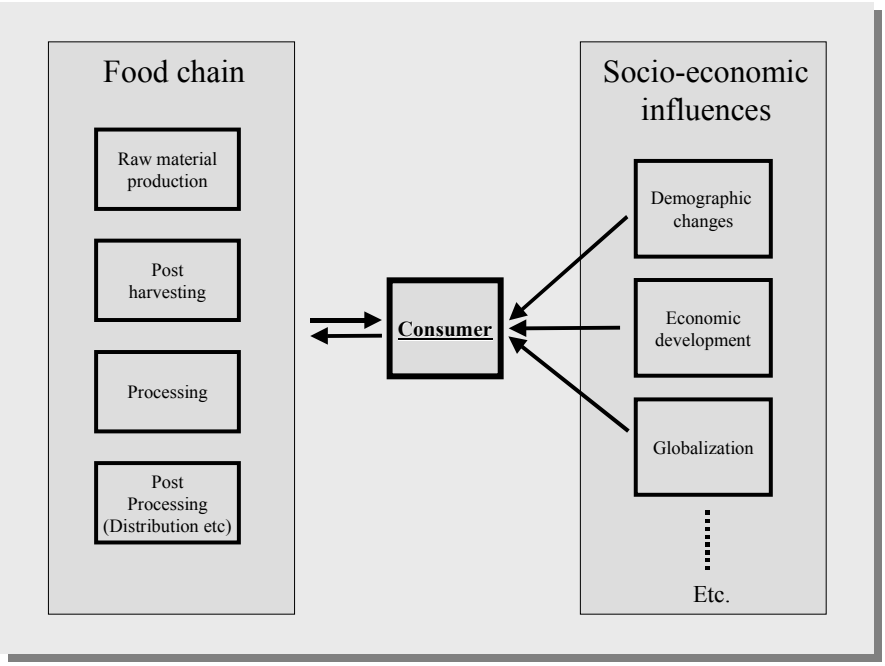

Figure 2: With the consumer in focus, the food chain activities are aimed at, and influenced by, the consumers, while the consumer needs and preferences are influenced by external socio-economic factors.

The consumer represents a very heterogeneous entity in the food chain. This becomes important in the moment the consumer is regarded as the key factor in the food chain. The socio-economic influences affecting the consumer are manifold as shown in figure 2. Factors like demographic changes leading to a stronger representation of the elderly in the future[7], the overall economic development, and the budget share per household, together with the effect of globalisation are decisive for the selection of food products). Influencing factors like these therefor play an important role for the anticipation of consumers' attitudes towards food and food processing and increased consumer satisfaction from food products.

The basic idea behind the reversed food chain thinking is the analysis of the interaction between the consumer and each individual phase of the food chain. Recent developments in the food sector (like the development of functional food, the use of GMOs in the food production or the BSE crisis) impressively showed the importance of the consumer sensitivity. Public perception cannot be neglected in any future development, be it food with modified nutritional properties or new distribution forms. This is represented in figure X by the double arrows between the food chain and the consumer.

Taking a closer look at the interaction between the food chain and the consumer, adding identified research clusters, the connection between the need for research and consumer benefits can be described along two different lines of issues (as shown in figure 3):

- *Horizontal issues*, which have an impact back from the consumer on the *entire* food chain, affecting each single stage:
  - Consumer trust and consumer satisfaction
  - Food safety and traceability
  - Sustainable food production systems
- *Specific issues*, which have special relevance for *individual parts* of the food chain:
  - Improved production of (new) raw material
  - Research of food material at the cellular/molecular level
  - New tools: Genetics and molecular technologies
  - Food product development/Product design
  - New technologies, optimising old technologies, minimal processing
  - New retail formats

[7] Although the total fertility rate increased in the last year, it still remains on a rather low level (1.54). At this level, the structural demographic shift towards a predominance of the elderly over the young population becomes firmly established. The net balance between birth, mortality and migration changes can be seen for example in "First results of the demographic data collection for 2000 in Europe", http://europa.eu.int/comm/eurostat/Public/datashop/print-product/EN?catalogue=Eurostat&product=KS-NK-01-015- -I-EN&mode=download

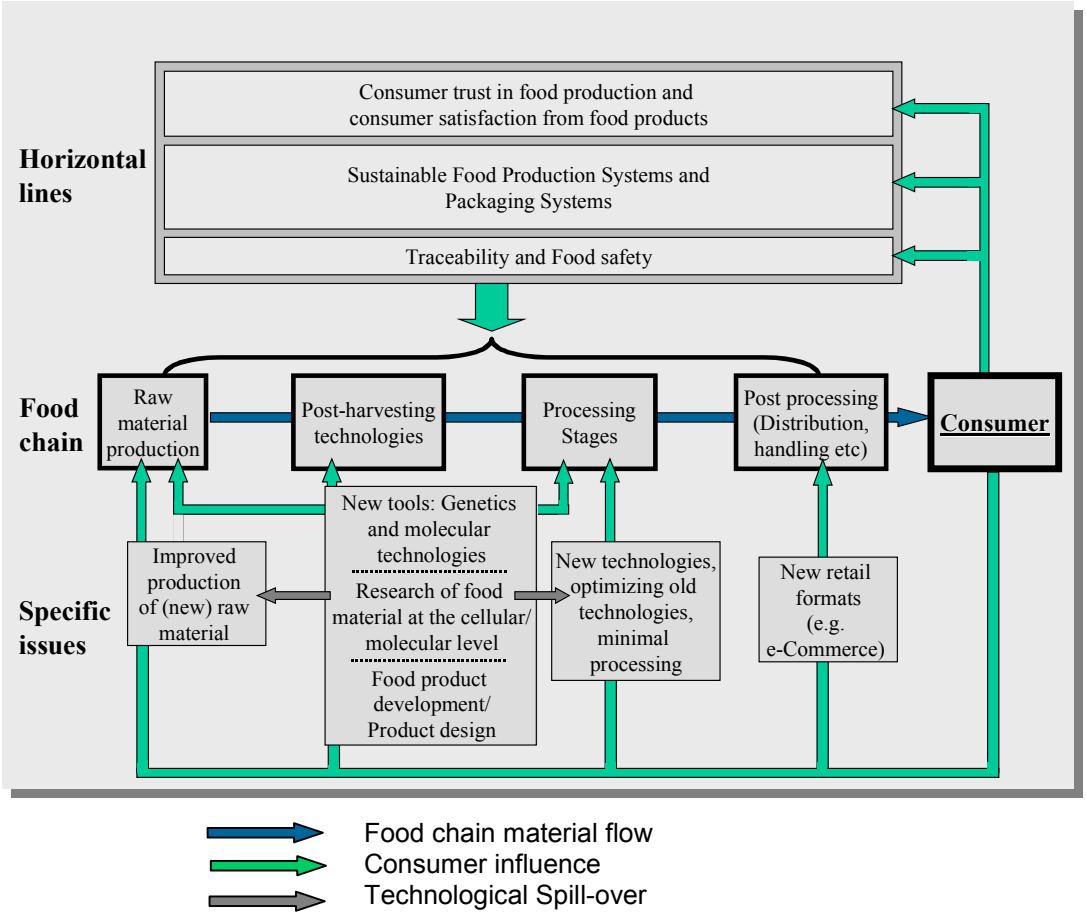

Figure 3: Reversed food chain thinking – From the plate to the farm

The first horizontal issue, consumer trust and consumer satisfaction, is determining all other issues and therefore requires a proper approach to understand the consumers perception of food and food processing. This demands the development of assessment tools in order to find out what benefits and risks the consumer assigns to the single steps of the food chain.

The consumer acceptance is indispensable for the introduction of new technologies into the food chain. The example of biotechnology in food production in Europe indicates that consumers will increasingly call for more information or even active involvement in decisions concerning new technologies in the food industry[8]. This fact gains further importance, as the technology basis of food production will be of increasing relevance for generating and seizing new business opportunities. In this context, research at the cellular and molecular level of food components will play a central role.

Although the high relevance of the consumers' point of view was perceived in relation with a series of food crises, this fundamental link should be taken into

[8] Eurobarometer 52.1: The Europeans and biotechnology, DG RTD, Brussels, 15 March 2000, pp.64-65.

account by decision-makers in policy and industry also in non-crisis situations. From an economic point of view, this development corresponds to experience already made in other markets – the shift from supply-driven markets to demand-driven markets. As food is one of the basic goods, this means that once a basic level of food supply is guaranteed or even exceeded, the consumer develops an increased interest in quality and variety. Through the ability to choose between a broad range of food products, the consumer acceptance of new food is the final criterion for a successful market introduction. Accordingly it will be necessary in the future to take the consumers point of view at every stage of food product development, processing and marketing into account.

2.2. European Research Area and FP6

Research strategies for the European food sector cannot be discussed in an institutional vacuum. Several initiatives, which are currently underway at the European level, have to be taken into account from the very beginning. One important parameter is the emerging European Research Area ERA. Following the ERA conception, research support has to result in a clear added value for the European citizen. Therefore the scope of establishing research priorities in the field of food technology and food safety is, among others, to determine which areas should receive public funding at European level rather than on a national basis, in order to obtain a European added value. Additionally, it should lead to spill over effects through transnational networks, therefore building European Centres of Excellence for specific issues.

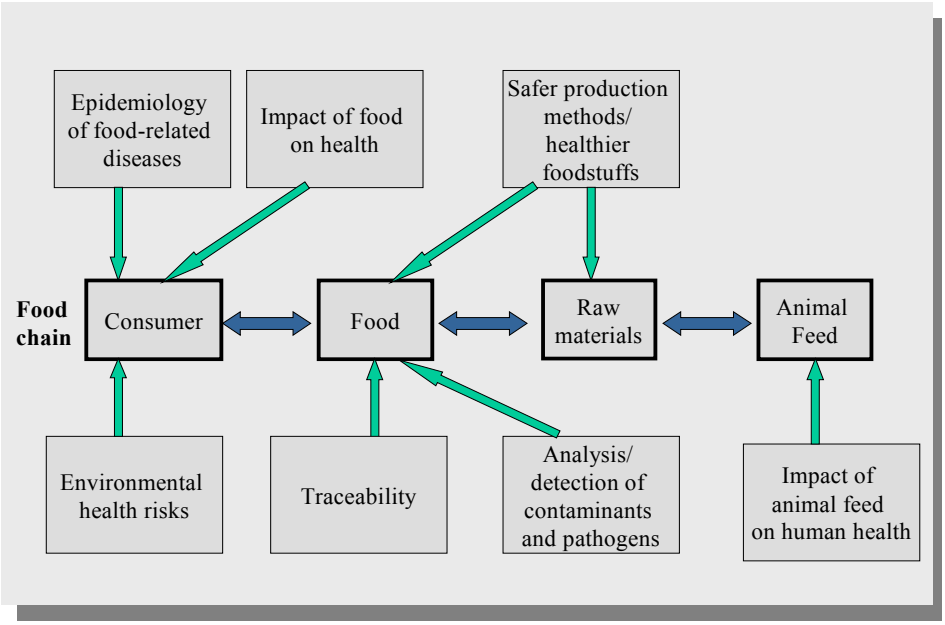

Fig. 4: FP6 – Thematic areas

Under this perspective, and under the impression of ongoing food crises, seven research areas have been defined in the sixth European framework programme for research. All of them are very close related to the issues “food safety” and “health”, and have a strong relevance at the European level. As these issues have been in the centre of an intense public debate, it is even more important to look at them from the consumers perspective and, consequently, to adapt them to the pattern of the “Reversed Food Chain Thinking” (Fig.4).

Three thematic clusters

Taking the European research strategy and the overall situation in the European food sector into consideration, the main challenge of the project was to come to precise and manageable research priorities, which strengthen specific areas in the food sector. The difficulty was to cover all relevant aspects of the individual priorities, which in some cases addressed different research areas at the same time. Looking for example at the issue “Traceability”, research priorities would have to comprise the technical aspect (developing technologies starting at the molecular level), the different stages of the food chain (how to actually implement traceability systems) and the consumer perspective (is the traceability system credible, and does it deliver information). The discussion throughout the project therefore gave rise to the idea, that the research areas as defined in the new framework programme of DG Research should be looked at from the three different perspectives (see Fig.5):

- Consumer Science
- Food Safety and Health
- Basic Food Science

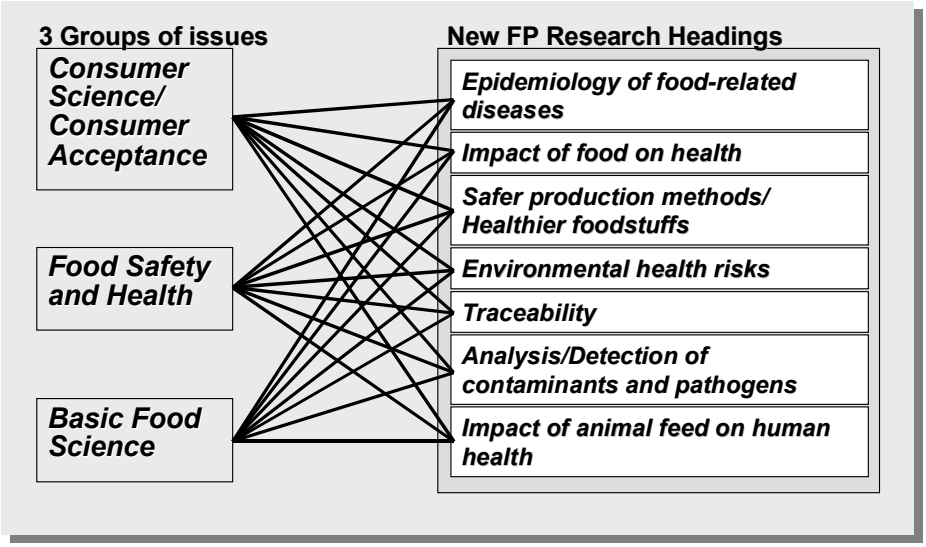

Figure 5: Research issues and the new framework programme

This perspective made it possible to come to a kind of hierarchical analysis of the research issues leading to explicit research priorities: Firstly the consumers needs and demands related to food safety and health were analysed, including questions of behavioural science and communication. Secondly a priority setting within the large landscape of food safety and health was done, developing first ideas how to tackle those topics. Here it is important to take into account the consumers' wishes/ worries/ perception of food safety and health. Finally the basic food science was examined on the one hand re-orienting the research focus to safety and health questions, and on the other hand developing new methodologies and instruments which are necessary to meet this demand.

Each of the three categories are addressed in the chapters 3 to 5. The specific relevance is explained in the introduction to each chapter, followed by description of the specific research priorities. Although tackled in different chapters, the three categories are overlapping and strongly interlinked. Therefore some of the priorities appear slightly modified under different headers. However, this seems to emphasise the need for increased research in these areas.

3. Priorities in the area of consumer science

The overriding theme of the project is the need to focus on the end consumer as the most important element in the food chain, and to re-construct the single elements of the food production and distribution process from the consumers perspective – in other words to start a reversed food chain thinking.

This approach requires a detailed knowledge of the characteristics of different consumer groups. Demographic changes lead to changing demands of consumers (for example the increasing group of elderly in the European society), their opinion is formed by a large variety of information sources. Regional differences between consumers such as different cultural values and preferences as well as the overall economic development also remain important parameters. These issues determine the framework for decision-makers in industry and governments when predicting future consumer behaviour and/or reacting to current unexpected market developments.

Starting from the consumer perspective, it should be noted that the information exchange between consumer and food producer should become a two ways communication, where food intrinsic attributes (studied by means of basic food science) may be translated into technological/functional characteristics (what is actually perceived by consumers).

European food consumers

In Europe socio-demographic trends are influencing the increase in consumers' demand on larger variety, enhanced nutritional value, convenience and affordability of foodstuffs. The reversed food chain thinking implies a deeper involvement of consumer needs and demands. The change from production orientation to demand orientation will cause a need to develop instruments in order to assess consumer attitudes, behaviour, preferences and values. Consumer attitudes and perception are closely linked to all aspects of daily life - combining societal conditions, psychological elements, technological level, level of economic freedom etc. This implies that the analysis of the consumer needs to be highly sophisticated, regarding the consumer more as a citizen and member of civil society, with values, dilemmas, etc. and as an actor in society.

The most important trend however is the generally higher income for most consumer groups. The relative share of the average household budget spent on food is therefore decreasing. In order to gain market shares on this very competitive consumer market companies are forced to launch new, innovative products faster than ever before. Companies therefore have to step up the pace of their research efforts. The companies' R&D processes have to move faster and be more effective to enable companies to gain a competitive edge. In order to match new products with different consumer segments the food industry makes frequent analysis of the needs of various consumer groups. The consumer knowledge is vital for the successful market introduction of new products. No novel food product can be introduced successfully on the

market, unless the consumers fully trust that it is safe (example: genetically modified foods)[9].However, even if the consumer is a very heterogeneous group, all consumers have a common requirement: The food has to be safe. Recent food crises/problems in Europe like BSE, other zoonoses, dioxins and other persistent contaminants have had a strong influence on the consumers risk perception. Food scares are effectively damaging the reputation of the entire food industry and can be very costly as recent estimates have demonstrated. In order to address food scares appropriate, a better understanding of consumer behaviour is necessary. Scientists and non-scientists do have a different perception of risks that has to be fully understood and taken into consideration. What has emerged from previous studies is that consumers use a different set of values, wider than the one of scientists, but not less valid. In particular hazards associated with risk of future generations are perceived especially severe by consumers. Risks that are difficult to quantify receive higher ranking in terms of perceived risk, irrespective of scientific evidence. Information and control are key factors. Consumers expect to be given the possibility of taking an informed choice. This factor enhances the value of clear and effective labelling.

In the light of the recent food crises and the subsequent policy debate, it seems appropriate to define two separate groups of research areas:

- Consumer behaviour under normal circumstances
- Impact of food crises on consumer behaviour

Naturally this distinction includes a strong simplification, as it would turn out difficult to define what represents a “normal situation” in the food area and even more in the consumer behaviour. Here obviously no reasonable benchmark is available. Nevertheless by introducing this division it is possible to emphasise deviations of consumer behaviour especially for the case of food crises.

[9]The IPTS Futures Project, Synthesis Report, IPTS Sevilla January 2000.

3.1 Consumer behaviour (under normal circumstances)

For the behaviour of the consumer in a “normal situation” on the food market, number of research issues were developed, which will be relevant in the mid-term future in the European context, having the criteria of the European Research Area concept in mind. It is notable that the focus lies on the keywords communication (channels), food safety, and health related to foodstuff – all issues pointing to the subject of food crises. The relevance of these topics is illustrated by the fact that the German Ministry for Consumer Protection announced a law for consumer information in 2001, which addresses consumer concerns related to recent food scandals.

In the following, the individual research priorities are outlined, which address the consumer behaviour under normal circumstances from the perspective of food safety and health.

P1 Determinants of perception of healthiness based on communication and physical product characteristics

Industry studies identify the health characteristics as one of the most important factors in the choice of foodstuffs in the developed countries, leading to increasing demand of healthy foodstuffs. The availability of a large variety of food products plays, in connection with education, an important role for balanced nutrition according to the food and drink industry in the EU. The industry considers the single market a priority in order to give consumers the right to choose foods with added nutrients in all Member States, i.e. foods that are safe and nutritious and can make an important contribution to the consumer's diet[10].

The consumer perception of food products can be characterised basically through a limited number of factors: The physical appearance of the product (shape, consistence, texture, taste etc), information delivered by the producer (labelling, information printed on the product/packaging, advertisement), and indirect information from other sources. These information flows shape the consumers opinion towards the product. It is clear that the average consumer is not able to analyse neither the ingredients of food products nor their impact on health, for this reason the “side-information” plays an important role. This indirect assessment leads to the risk that the consumer opinion, particularly concerning the healthiness of food products, is only partially fact-based. As an example serves the widespread belief that organic food is healthier than conventional food, although this has not been proven up to now.

The first research question emerging directly from this situation is: How can the consumer perception of healthiness be addressed?

One approach is to focus on the communication (channels) between consumers, food producers, public authorities and third parties. How does the consumer learn about the product? How credible is the communication? What is their preferred indirect information source?

[10]Confederation of the Food and Drink Industries of the EU, addition of nutrients to foods: meeting consumer needs for safe and nutritious foods, Positions, 03.07.2000.

A second research issue arising in this context is the question of how the sensory characteristics of a food product (taste, smell, texture) influence the perception of healthiness of the consumer.

This question implies that the consumer prefers food products which not only have enhanced health characteristics, but also “taste healthy”.

P2 Foods designed for special interest groups meeting nutritional, sensory and functional requirements

The development of new food products, with improved effects on health like in functional foods, requires the definition of market segments, as different target groups demand different nutritional supplies. Recent demographic developments in Europe or parts of EU lead to new challenges as well as opportunities for the food industry. The increasing share of retired citizens should be addressed by food especially designed for their needs, the multicultural society of today leads to a higher demand for "exotic food" and the increased number of single household has given rise to many new packaging and vending solutions aimed at increasing convenience[11]. This research issue points into the direction of work already done in the area of functional food, but enlarging the scope to more specified target groups[12]. Besides these still rather large groups, research should also be carried out in the development of food products for special interest groups, like for example sportive people, or persons with specific dietary needs.

P3 Labelling
– Labels as credibility signal
– Communication in credibility alliances
– Design of labels based on behavioural science

As already mentioned, the information delivered together with the food product is one of the main communication channels in order to address the consumer. In this context, labelling plays an increasingly important role. This is highlighted by the European labelling directive 2000/13/EC, which aims at ensuring that the consumer gets all the essential/objective information as regards the composition of the product, the manufacturer, methods of storage and preparation, etc[13]. For GMOs in the food chain, the Commission proposed a regulation in 2001, which would make labelling for all food produced from GMOs mandatory[14].

Labelling enables consumers to take informed decisions. At the same time there is the risk that products are overloaded with information on ingredients, origin, production processes, environmental friendliness of the product and/or the packaging, compliance with standards etc. It has been proven in field studies that consumers either do not read the information in detail, or, even

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[11] "First results of the demographic data collection for 2000 in Europe", http://europa.eu.int/comm/eurostat/Public/datashop/print-product/EN?catalogue=Eurostat&product=KS-NK-01-015-__-I-EN&mode=download, "100 basic indicators from Eurostat Yearbook 2001 – the statistical guide to Europe", http://www.europa.eu.int/comm/eurostat/Public/datashop/print-product/EN?catalogue=Eurostat&product=100indic__-EN&type=pdf

[12] A very good overview of the issue is given in "Technology Assessment - Functional Food, Zentrum für Technologiefolgen- Abschätzung beim Schweizerischer Wissenschafts- und Technologierat, Bern, 2001"

[13] http://europa.eu.int/comm/food/fs/fl/fl01_en.pdf

[14] http://europa.eu.int/comm/dgs/health_consumer/library/press/press172_en.pdf, and http://europa.eu.int/eur-lex/en/com/pdf/2001/en_501PC0425.pdf

worse, do not understand it. Against this background, a number of different research questions emerge as important.

Firstly, the role of labels as credibility signals has to be analysed. Consumer communication is often enhanced through the use of labelling systems organised by credible consumer organisations or NGOs. It can be observed already today that labels from this perspective develop into a marketing tool, which is desirable for companies.

In the same direction point the potential installation of "credibility alliances", bringing together food producers and independent organisations with high credibility. A research topic is if and to which degree such alliances are able to reinforce the direct communication between producers and consumers. A prominent example is the engagement of Unilever with the Marine Stewardship Council, a NGO in the area of fisheries and marine conservation.

Secondly, research effort is needed on the design of labels in order to make them understandable for consumers. Therefore it is necessary to understand how the information uptake works, which information is important etc. Research in this area should be interdisciplinary, as for example elements from behavioural science play a central role in tackling this question.

Finally, the application of bioinformatics and the use of barcodes should be analysed in order to access new possibilities of information transport. In this context it is important to keep in mind that the information should ease on the one hand the processing along the individual stages of the food chain, and that specific information has to be derived for the consumer.

P4 Traceability from a consumer viewpoint
– Consumer information demand
– Trust
– Differentiation and Segregation

Traceability has been defined by ISO as the ability to trace the history, application or location of any entity by means of recorded identifications. Looking at recent food crises, the importance of traceability systems for the food chain is evident. Therefore, traceability has already been an issue under the fifth framework programme, and it stands still very high on the agenda[15]. Traceability systems serve for several purposes. Firstly, in order to provide the consumer with his preferred information concerning origin of foodstuff and/or processing ingredients, traceability systems are the adequate tool for generating this information efficiently. It should be kept in mind that content and form of the information would have to be designed according to consumer needs (see "Labelling" above). Secondly, but correlated with the first point, the ability of traceability systems to generate consumer trust should be analysed. Here the question is to look at the function of visible and transparently applied traceability systems as a signal for credibility, even if the consumer receives only a condensed amount of information. A final research question addresses

[15] FP5, Quality of Life and Management of Living Resources Programme, Key Action 1.

traceability as a prerequisite for (increased) differentiation of products starting from primary production throughout the entire food chain. Differentiation of products enables the producer to address different consumer groups and therefore increases consumer satisfaction.

At the same time, the producer need of identifying the cause of food defects (low-quality raw material, malfunction in the production process etc.) can best be served with comprehensive traceability systems. Therefore the ongoing research in the area of traceability concerning the application of IT systems along the food chain, the identification and definition of traceable units, the implementation of HACCP aspects etc should be increased.

P5 New purchase patterns, information technology and health and safety

At the consumer end of the food chain, retailing has profound impacts back on the entire food system. Building on the information technology infrastructure established with the introduction of scanning and electronic data interchange in the 1970s and 1980s, widespread adoption of new technologies and business practices are designed to eliminate inefficiencies throughout the retail food supply chain. Individual food stores, food store group headquarters, distributors, and manufacturers invested in new information technologies designed to promote additional supply chain efficiency gains. Electronic commerce also emerges as a major issue, with increased emphasis placed on the development of business-to-business applications. The move from proprietary electronic data interchange (EDI) systems to web-based systems is making it easier to extend the benefits of e-commerce beyond the manufacturing plant and distribution center to the store level. New technologies include systems to facilitate faster transfer of product movement data and product orders, electronic assisted receiving, frequent shopper cards, and shelf-space allocation software. New business practices include vendor managed inventory, scan-based trading, and the information and decision sharing that is part of many category management programs. The retailing sector is actually one important factor explaining the exceptional economic growth of the US economy during the 1990s[16]. Due to the implementation of information technology and a general increase in store sizes, labour productivity in the retailing sector increased dramatically, resulting in lower consumer prices and increased consumption.

Internet retailing of food products directly to consumers has yet not been successfully introduced on a large scale basis. With increased domestic internet use, improved logistics and adapted packaging systems, a broader diffusion of this technology seems probable within the next 5 to 10 years. In such a scenario, the communication between the food retailer and the consumer could be developed into a new way of offering food products. Diets could be proposed based on nutritional content, and sold as preset packages. For the retailer, internet retailing could mean reduced costs in the long run, while for the consumer the buying process could be simplified and tailored to his needs.

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[16] McKinsey Global Institute. 2001."US Productivity Growth 1995-2000 - Understanding the contribution of Information Technology relative to other factors". Washington, DC October 2001

Information technology will not only lead to new forms of retailing and shopping, but also to applications in the household, like intelligent refrigerators which monitor the deterioration of food products, new forms of cooking technologies etc. The development and application of new technologies in this area might lead to new combinations in the way how food is being bought, stored, and put together into meals, also in the context of food safety and health.

First prototypes of "intelligent" household/kitchen technology have already been introduced to the market. Nevertheless standards and norms have to be developed for the linkage and communication between the different technical platforms as well as for the connection with developing distribution and purchasing systems.

To take advantage of technological progress, the implementation of modern information technology in the European retailing sector is a key research area. The potential benefits are large for both consumers and the European industry.

P6 Life style and calorie management in the diet

A more general approach shifts the focus from the individual food products towards providing a more balanced and personalised diet. This comprehensive perspective bases on the argument that the overall objective of food producers should be to sell diets instead of products to the consumer. Therefore this research issue addresses the question how the exchange of personalised nutritional information with the consumer can be realised, how food availability can be matched with consumption habits and life styles, and how the consumer can be enabled to manage his calorie consumption in an easy and efficient way.

P7 Consumer willingness to pay for increased quality and healthiness

Increased health characteristics and nutritional values as well as applied traceability systems for better information and food safety will probably lead to higher end prices for food products. This does not necessarily lead to market distortions, as consumers are prepared to pay higher prices for higher quality and increased convenience. Many consumers are also ready to pay more for environment-friendly productions. When people move into middle-income levels, not only does their food consumption increase, but the demand for food that combines variety and quality with economy and nutrition also increases. In the food sector, price elasticity within a homogeneous product category is rather low: if the price increases for one product, consumers tend to choose a similar product at a lower price. Therefore the research question here is to develop methods to measure the willingness to pay (more) for new food products before they come to the market. There is also a lack of systematic analysis "ex post" of the willingness to pay of consumers for already introduced products.

Models analysing the consumer willingness to pay for benefits have already been developed in the area of environmental economics and might serve as a prototype for similar research in the area of food safety.

P8 Consumer perception of new food technologies

As the European debate on genetically modified food has shown, consumers form an opinion on new food products, even if they do not fully understand the applied technology and the new production process[17]. Certainly this debate is an exceptional case, as the positions have become rather polarised and a state of technology focused conflict has been reached[18].

The debate on GM food could nevertheless be an indicator for a more general phenomenon. Consumers do not understand modern food production, but as they are directly affected by this development, they have/share opinions with regard to food technologies. At the same time the acceptance of new food products (also those enhancing food quality and healthiness) obtained by means of new technologies depends on the acceptance of these technologies. An acceptance problem does therefore not necessarily arise from a technological problem, but from the consumer perception of this technology. Therefore the underlying mechanisms how consumers perceive new technologies have to be explored.

3.2 Impact of food crises on consumer behaviour

Triggered by the series of recent food scandals such as BSE or dioxins in chicken, the experts at the IPTS workshop additionally developed research issues concerning the behaviour of consumers in the case of food crises.

Although the research issues presented in point 3.1 already include a strong element of food safety (e.g. through proposed research on traceability systems and labelling) and therefore point at strategies on how to avoid future food crises, the following research issues explicitly address the situation where a food crisis has already occurred.

P9 Risk perception, information demand and communication in a crisis situation

Normally consumers are less interested in information concerning food, as food is usually regarded to be safe. This changes in the case of a food crisis. Information demand increases dramatically, and information exchange exceeds the direct communication between producer and consumer and involves third parties such as NGOs, media, and governmental authorities. The question to be analysed in this context is: What kind of specific information does the food consumer demand in this situation, which are the important and credible sources for information gathering, how can systematic

[17] Eurobarometer 46.1 "The Europeans and Modern Biotechnology", European Commission, Luxembourg 1997.

[18] A very good description of this development from discussion to societal conflict in the case of GM food has been given by J. Tait: "More Faust than Frankenstein: the European Debate about the Precautionary Principle and Risk Regulation for Genetically Modified Crops", *Journal of Risk Research* **4**(2), 175-189 (2001).

information channels for these (worst scenario) cases be developed in order to contain a food crisis.

P10 Analysis of amplification of food crises

How are food crises developing? Why do certain incidents develop into a "food crisis" with a lot of media attention, and others do not? How do the various stakeholders (consumer groups/NGOs, food authorities, industry etc.) behave and interact? There has been research on these mechanisms in other areas, but not in the food sector. It would be valuable to analyse the existing cases such as BSE, in order to reveal patterns, which are common for those cases, and which subsequently allow decision makers in governments and industry to develop adequate strategies in order to react quickly and efficiently to emerging food crises.

P11 Food crisis containment

The development of food crises shows usually two lines: one is the physical cause leading to an undesired effect in food production (such as prions in the case of BSE), the other one is the exchange and handling of information about the crisis. While the first line is handled with technical-analytical methods, the information exchange tends to develop a different dynamic. At the beginning of a food crisis, when information is spread in a rather uncoordinated way between industry, regulators, and consumers, consumer behaviour can have a strong impact on the market, but tends to return to the previous status before the crisis is under control from a technical point of view. This is illustrated by the fact that in the case of BSE, main questions such as the way of transmission. remain unsolved, while the demand for beef increased nearly to the "before-BSE" level.

In the case of a food crisis it is particularly for these situations interesting to analyse, which common factors are facilitating the return to the "ex ante" situation, and which factors are crucial for re-establishing consumer trust.

4. Priorities in the area of Safety and Health

With regard to the new research programme the issues related to safety and health in the food chain are at the top end of the political agenda. Although the topics are strongly interrelated, the two tracks “Safety” and “Health” are treated separately. This is done in order to identify important research issues which have a limited scope but a high relevance. One example is the development of HACCP type control mechanisms along the food chain to increase/monitor food safety - the short-term effect on human health is in this case more indirect. On the other side there is the example of functional food which mainly covers health issues with less relevance for the safety analysis. Therefore the discussion concentrates separately on the safety issue in chapter 4.1, folllowed by the discussion on health impact issues in 4.2. The research priorities, derived from both discussions, are then presented jointly in chapter 4.3.

4.1 Food Safety

Safety in the food chain should be looked at in terms of microbial and chemical issues (see figure 6). This approach assumes, that the main challenge to food safety arises on the one hand from undesired chemical components in foodstuff, or through uncontrolled microbiological activity, (entering through raw material at the starting point of the food chain or via contamination during the processing). One obvious method to cope with this challenge is the detection at the earliest possible stage of the food chain.

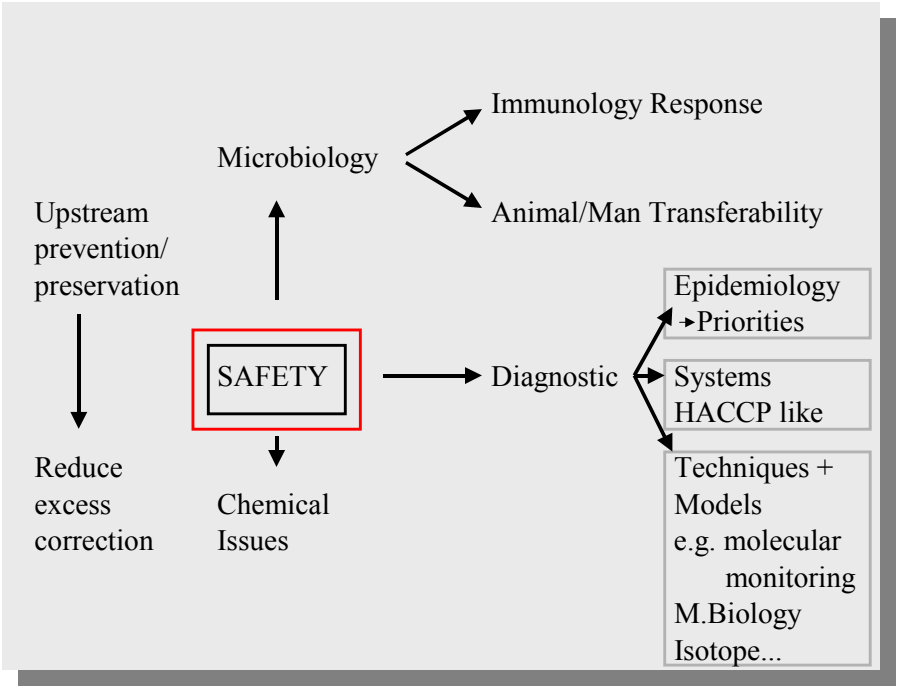

Figure 6: Safety needs in the food chain

Therefore diagnostic tools have to be developed for the entire food chain, which guarantee a maximum degree of prevention of food safety problems resp. preservation of food quality. The focus for the development of diagnostic tools should again be the starting point of the food chain, close to the raw material production, in order to refrain from avoidable follow up interventions or even the recall of food products from purchase end-points/consumers.

The use of molecular monitoring techniques and the increased substitution of animal trials for tissue models are two examples of how diagnostic tools are being improved. “Diagnostic” not only means analytical methods, it also means to establish epidemiological priorities, decisions have to be made concerning what is considered to be really critical. Analysis usually concentrates on one target substance, be it chemical or microbial. In order to set priorities on how to spend scarce (financial) resources it has to be discussed if e.g. research for the early detection of listeria is more important than the detection of salmonella.

Already existing models can be used for the development of instruments tailored for the food chain, and here the HACCP-systems (Hazard Analysis Critical Control Point) should be developed further.

4.2 Health

Contrary to the risk prevention/quality maintenance focus of the discussion of the safety issue (4.1), this health issue regards the potential benefits of food products. A division is made between, on the one hand, nutritional improvements are looked at, and on the other hand the role of active molecules, as it is understood in the context of functional food (see figure 7). At the same time it is necessary to analyse the interaction between micro-organisms in foodstuff and the human metabolism. This can comprise positive, health improving or negative, health damaging effects.

Diagnostic tools have to be developed, similarly to the safety issue. Regarding allergies, cardiovascular diseases etc, no consolidated European wide epidemiological study is available at the moment, leading to action priorities accepted widely among stakeholders. Those would lead to prevention strategies, for which again techniques and models are necessary in order to identify health problems and to develop recommendations. Solution approaches might tackle obesity and other pathologies and may include genetic tools, diet behaviour, etc.

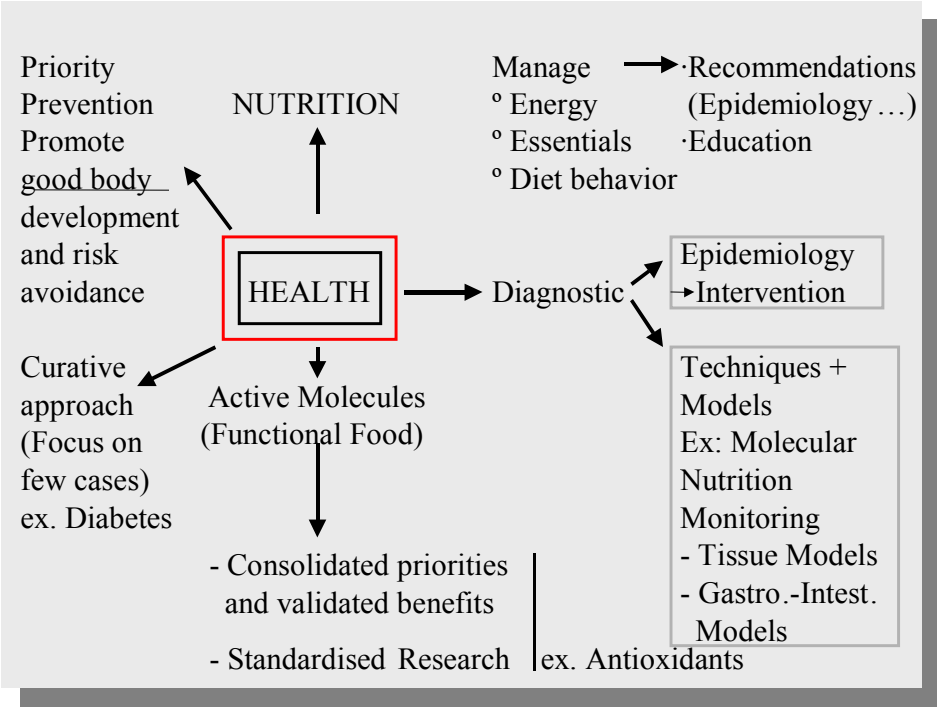

Figure 7: Health issues related to the food chain

Nutrition

A way forward to increase the nutritional value of food could be based on molecular nutrition. In this context could the carbon associated to certain carbohydrates should be examined in order trace its efficient use in energy consumption. Those methods already exist and are used, for instance in tissue models.

One could also think of producing food with a therapeutic effect, such as food against diabetes. This is an opportunity, but it has to be discussed if this is not an issue outside the food technology/food safety area and should therefore be left to medical authorities.

Active molecules, as understood in functional food.

Active molecules: Currently no consolidated work is done on e.g. antioxidants. It is the one example where a lot of coherent data is available, but which is not processed in a comprehensive analysis concerning the beneficial effect of antioxidants in specific products (e.g. wine, food etc.). This analysis has to be done in a standardised way which makes it possible to compare different results.

4.3 Research Issues

On the basis of the discussion around the safety and health issues related to food processes and food products, a number of direct research priorities can be formulated.

P12 Immunological system/Bacterial interaction in the colon

Further investigation is needed on the interaction of the immunological system with bacteria, be it beneficial or harmful ("good" or "bad" bacteria). A starting point here is to establish whether there is a problem of antibiotic resistance or other health problems associated with pathogens etc. The ban of antibiotics as growth promoters for the animal husbandry, as well as the introduction on the European market over the last years of numerous probiotic products for human consumption, have strengthened the need to study the potential negative aspects of the extended use of lactobacilli (LAB) in food and feed products and in probiotic preparations. In recent years, a number of clinical reports indicated the association of some LAB with an increasing incidence of human infections such as endocarditis or sepsis. With the exception of the pathogenic *Streptococcus* spp. and some enterococci, little is known about factors that may be linked to virulence of lactobacilli strains involved in human infections.[19]

Numerous reports link beneficial health effects to species of Gram positives (e.g. *Propionibacterium, Bacillus*), Gram negatives (e.g. *Eschershia coli*), yeasts (e.g. *Candida, Saccharomyces*) and fungi (e.g.*Aspargillus*). Isolation and characterisation of Bifidobacteria animalis (not of human origin) and in some instances, the viable counts of Bifidobacteria in some products makes the probiotic afficary of such products questionable. Future research activities need to concentrate on the integration of raw materials, microbial systems, processing distribution, storage, preparation and consumption in order to better understand and monitor microbial viability and productivity as well as product functionality. The main problem is that many of the health-promoting properties mentioned above are still questioned. For instance, the fundamental basis of the inhibition of Gram-negative pathogenic microorganisms - like enterovirulent, diarrheagenic *Escherichia coli* and *Salmonella typhimurium*, and *Helicobacter pylori* causing gastritis and peptic ulcer disease -, by probiotic lactic acid bacteria strains has not yet been elucidated.

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[19] Until now, no evidence has been found to link LAB strains with the consumption of fermented foods or probiotics. The clinical significance of other lactobacilli in human infections is poorly understood because of the scarcity of well-documented reports. However, two recent publications suggested the involvement of "probiotic" strains of LAB with cases of endocarditis (Mackay, A.D., *et al*. (1999). "*Lactobacillus* endocarditis by a probiotic organism". Clin. Microbiol.Infect. 5, 290-292.) and a liver abscess (Rahman M. (1982) "Chest infection caused by *Lactobacillus casei* ss. *Rhamnosus"*. British Medical Journal 284, 471-472. It is noteworthy that most lactobacilli strains isolated from clinical cases thus far, belong to the species *L. rhamnosus* and *L. casei*, although other species are also involved (Gasser, F. (1994). "Safety of lactic acid bacteria and their occurrence in human clinical infections". Bull. Inst. Pasteur 92, 45-67).

In addition, the mechanism responsible for the so-called bifidogenic effect, in particular with respect to the inhibition of pathogenic, Gram-negative micro-organisms, has not been approved. However, recent reports have suggested the potential role of probiotics in gastroenterology therapies. Further studies are needed to evaluate the possible role of probiotics in the treatment of *H. pylori* infection and other infectious diseases. Probiotics are a promising alternative to the use of antibiotics and hence avoid further development of antibiotic resistance. Another example is infants acute diarrhea. Infants and young children are particularly susceptible to the ill-effects of diarrhea. Gastroenteritis can be caused by a variety of pathogens including rotavirus, *E. coli* and *Campylobacter*. Certain probiotics have been found to be helpful in preventing and treating some types of bacterial-induced diarrhea because of their ability to alter the activity of the intestinal microflora and compete with potential pathogens.

Thus, research on the interaction between the immunological system and natural existing bacteria needs to be prioritised. In the USA major advances in understanding this interaction have been made, which will make it possible to rethink antibiotic strategy, to rethink microbial flora etc. This points into the direction of an “indirect” research question: Food for healthy consumers should not be sterile, because this may represent the risk of diminishing the immunological system.

Research approaches have to assemble and combine the already available knowledge: What do we know about the relation between immunological system, how does it work, etc. For this objective models are needed, and molecular biology is the simplest tool to trace the real effect.

P13 Bioefficacy understanding - advanced techniques for molecular monitoring

Research efforts should be increased in the area of molecular monitoring. This serves not only to trace the bioavailability of ingredients and additives, but also the bioefficacy. The question behind this reaches beyond the pure availability of substances – it has also to be examined if they are distributed in the organism towards their most efficient use.

As an example may serve the addition of calcium in milk (being preventive against osteoporosis). Many companies now add calcium to a variety of foodstuffs, for example in orange juice. In this way it is made more available in the diet. But it is also important to understand the mechanism of fixation and following depletion of calcium, so that its integration may be more targeted. Therefore calcium does not have to be in all food and beverage.

Again, this research issue refers to understanding processes at the molecular level.

P14 European consolidated epidemiological information, recommendations and priorities

There should be a European project on consolidated available epidemiology facts, leading to recommendations for food safety and health. Sensitive groups should be identified, in order to be able to tackle a problem of a specific, sensitive consumer group with a specific solution. If a too generic approach is applied, a mismatch between target group and nutritional food supply could emerge at the distribution level, which potentially could develop into a food crisis.

What is needed here is an indicator referring to priorities. Currently in Europe there are 15 million women at risk of osteoporosis. In China for example they are hundreds of millions. This makes the priority clear for an individual company, as long as it acts globally. In Europe this can be different, as for example the research on cardiovascular diseases might have a higher priority. Maybe there is already a sufficient reduction of fat in food, and subsequently osteoporosis prevention could have a higher priority. Therefore consolidated analysis of data concerning epidemiological facts in Europe is necessary in order to get a proper ranking of priorities. This is especially important for companies, as they try to move along the lines of European research. One proposal is to observe the 0-14 year group as a pilot group. It has to be investigated what are the epidemiological needs of the group, what is lacking, etc. Than the appropriate recommendations for optimisation have to be generated, an interventional follow-up has to be carried out, and the group should be monitored over a long-term period.

A similar study exists already in the USA (the Nurses model), delivering reliable and credible results to the Boston School, and a similar approach for Europe would be highly recommendable.

P15 Identify consumer priorities (wishes) for safety & health and develop solution strategies validated by scientific experts

Safety research is generally designed from the viewpoint of scientists. Therefore, it is important to analyse, how consumers “translate” or perceive their acquired knowledge. This is important and should be treated in close relation to the results discussed in chapter 3 “Consumer Science”. The analysis should make it possible to develop consumer-tailored solutions, which bring together the scientists and consumers views of safety and avoid misunderstandings.

P16 Establish HACCP equivalent methodology for risk assessment to maximise upstream prevention

Recent food crises and the increasing industrialisation of food production strengthens the existing trend to make the entire food chain transparent and controllable. In practise this turns out to be difficult. A more feasible approach would be the identification of upstream control points, but today there is no methodology that allows to find out those points.

Therefore research in this area is considered necessary and, following the above discussed logic, the focus in the identification of control points should

be placed on raw material control and quality preservation, in order to avoid excessive processing and (too) late control and intervention opportunities.

The application of HACCP-like methodology seems to be useful, because once the critical control/action points are identified (besides the high quality of raw/input material), a better link to traceability and consequently to consumer communication will be possible. New tools in risk assessment and new advances in HACCP training, HACCP system management and implementation will assist the industry in dealing with current and emerging food-borne hazards. The aim is not only to guarantee the quality of the output and to have a better control over the process, but also to safeguard the traceability through the different links of the food industry and of the food chain (e.g. by Good Manufacturing Practices, ethical audits, HACCP, etc.).

P17 Develop anticipatory/predictive risk methodology with two main objectives:
- Priorities development
- Preparation of competences and analytical methodology

The response to food crises has been rather reactive/passive in the past, lacking an anticipatory/pro-active approach. This led in a number of cases to quite "ad-hoc" counterstrategies and, consequently, to an uncontrolled development of food crises with a very negative effect on public perception and discussion.

Prevention methodologies already exist within companies (risk assessment etc.), but there is no uniform European approach. This methodology could be adopted for a number of cases (listeria, salmonella etc.), the relevant priorities would have to be developed. This would allow to prevent situation where the authorities and the companies are taken by surprise by unexpected food problems, not having the competencies, or the analytical techniques to deal with, for example, prion detection in beef.

Answers to this research question will help to manage food safety problems in an anticipatory way.

P18 Availability of healthy food - Resolve technological hurdles:
- Low sensory quality of desirable ingredients
- High cost
- Maintain calorie management: Bulk & Satiety

The question here is how to increase the availability of healthier foods. Key words are "Enjoyable safety" and "Enjoyable health", which means that food products with improved effects on health should not only be perceived as useful, but also as desirable by the consumer. Improvement of the sensory quality of desirable ingredients is one way. Reducing the cost of desired ingredients is another way, e.g. for Fructo-oligosaccarides.

In this context also the issue of calorie management has to be discussed: The challenge is to bring back/preserve bulk to food (and satiety and pleasure that are related to it), if at the same time calories are reduced. The main aim is to reduce risks associated with obesity, and the research issue is to develop the appropriate food.

In the field of taste preservation another tool may be offered by production of recombinant enzymes, currently under investigation. By combining gene segments from range of related enzymes, it is possible to alter substrate preference, regio-specificity, stability or tolerance to organic solvents or even to create enzymes with entirely new properties. Research is underway on lipoxygenases, which form short chains of aldehydes and alcohols and are responsible for the natural aromas of fruits and vegetables. The enzymatic synthesis of "natural" aromatic compounds, by using recombinant enzymes, offers the additional advantage over chemical methods that the products will be chirally pure.

P19 On-line monitoring techniques, based on molecular tracing: Metabolic risk factors or desirable raw ingredient components (Bioactive molecules)

Most common conventional techniques for process analysis and control in food stuffs are gas chromatography, HPLC, mass spectroscopy, and atomic absorption spectroscopy, while in routine analysis techniques such as UV/VIS spectrophotometry are widely used. Usually these controls are carried out using one of several off-line methods. This involves manually removing a sterile sample from the production line for analysis. There are inherent problems with this approach. Off-line systems can be time consuming, laborious and may not reflect the real time status of process. For these reasons, it is desirable to integrate standard tests with preventive analytical activity: this activity needs more specific, simple and low cost methods.

The prevailing idea for this research priority, in terms of monitoring, is to develop on-line monitoring techniques based on molecular tracing for e.g. metabolic risk factors or desirable raw ingredient components. This means that, if there is a marker for particular pathogens, this can be traced online. The idea is to use biochip techniques etc. These techniques do allow to do mass analysis as opposed to the very specific analyses done at the moment. In other words, food can now be mass- scanned in contrary to looking at one sample. These techniques now become available thanks to molecular biology technologies.

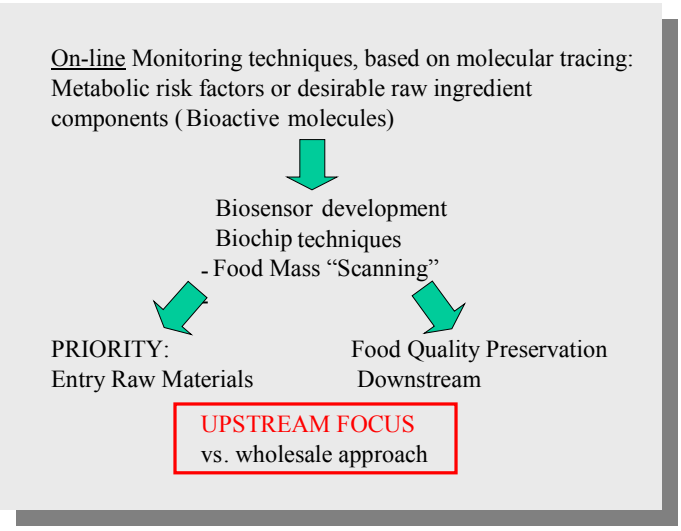

Fig.8: On-line monitoring techniques

This includes the whole notion of molecular tracing, it applies to the diagnostics, to the efficacy tracing (see above “bioefficacy”), and the same knowledge can be used for the development of sensors and quality monitoring throughout the whole process.

Nanotechnology as well as biochip techniques can be used here. The resulting monitoring capacity allows to control the high quality of the entry components into the food production and maintaining it all along the food chain, without the necessity of later intervention in the process. This is called “Downstream food quality preservation”, as shown in figure 8.

Excursus: Monitoring of dairy products

The screening of milk for antibiotics is a very important issue in the production of dairy products. Antibiotic residues are found in milk from cows treated for bacterial infections using antibiotics. These residues are an important public health issue, being potential causes of both allergic reactions and the development of bacterial resistance to antibiotics. Maximum residue limits (MRLs) for the presence of antibiotics in food, including milk, are defined in the EU regulations. In addition to the question of public health, antibiotic residues have an inhibitory affect of starter cultures of bacteria used to make fermented milk products such as cheese and yoghurt.

Existing methods for the detection of antibiotic residues are largely based on the use of physicochemical or microbial inhibition tests. Microbial tests are slow and do not attain sensitivity at the MRL level, while physicochemical methods are labour intensive and must be carried out in a laboratory. On-site tests such as CHARM or SNAP currently used by dairy tankers suffer from serious drawback in that they only test for a restricted number of antibiotics, and their use is relatively complicated. An alternative approach is the use of optical immuno-sensors based on waveguides. The development of low-cost optical waveguide chips allows them to be used as disposables, avoiding problems of cross-contamination and lengthy cleaning steps. Recent developments engineering in the use of “imprinted smart” polymers along with supercritical extraction, reverse micells, and liquid membranes will allow for selective removal of specific components.

P20 Investigate Animal – Man/Plant – Man Transferability

Looking at recent food crises, the topic of transferability from animal and plant to man is gaining evidence with regards to BSE.

The full traceability for beef labelling from producer to retailer will become compulsory in January 2002 in the EU. Meanwhile many different areas of research urgently need a co-ordinated public research effort. Among them, study of BSE/TSE related pathologies are high on the agenda. Too little is known of the intra/interspecific transmission mechanisms. Where are the prions (proteinaceous infectious particle lacking nucleic acids), which are possible vehicles and vectors and eventual “co-factors”. Resistance of this “infectious particle” to more common treatments, such as sterilization/decontamination techniques on feed processing equipment, in the abattoirs and in the animal food processing equipment need exhaustive

research efforts. What happens in animal species (and in their edible tissues) that do not develop the disease has to be definitively cleared. Testing methods in alive cattle and rapid diagnostic tools for discriminating risk materials in different food or feed matrixes are also urgently needed. European Regulations enforcement need quite a lot of diagnostic tools, for example to avoid the usage, according to precautionary principle, of possible food ingredients coming from risk material or that could be cross-contaminated (gelatine, blood, rendered fats etc.) in food formulas, cosmetics and pharmaceutical drugs.

5. Basic Food Science

This chapter discusses future research strategies for basic research in food technology, defined here as the physical, chemical and biological characteristics of food through all phases of its production and processing, starting from the raw material and ending with its supply to the consumer. Basic research is needed to support the present and future applied developments in all areas affecting the consumers' wellbeing.

Basic research on molecular technologies and genetics

One issue that played an important role throughout the entire project was the high relevance of molecular technologies for R&D in the future European food sector.

Molecular technologies and genetics are representing a major tool in the development of novel food raw materials and/or food components and a powerful tool for diagnostic purposes. One of the main efforts in molecular technologies is currently devoted to better understanding of specific genes functions, related expression and molecular cell structures (e.g.: cell membranes or walls) or even specific food tissues. Academic basic research is oriented in relating structure and functionality in food systems at the molecular or cellular level. Moreover a more in depth knowledge of metabolic pathways allows their partial modification in order to increase concentration of useful metabolites or rather decrease undesirable or toxic food components (natural toxicants, antinutritional factors, undesirable components etc..). The enhancement in concentration of specific nutrients is obtained by introducing new biosynthesis pathways into specific staple foods. The most wellknown example is the addition of provitamin A into rice endosperm, which makes it possible to overcome specific nutritional deficiencies in populations living on rice as major staple food. On the contrary reduction/suppression of specific components may be obtained with antisense techniques.

European standardisation of research results

Standardised research protocols would mark an important step ahead in realising synergetic effects in European basic food research. The community of public researchers need to communicate more efficiently within the research community and with the food industry and the policy makers as well as with the consumers. Standardisation is needed both in the elaboration of analytical protocols and of methodological tools. Frequently addressed cases are specific post-marketing monitoring programs using controlled groups of populations, for example for GM food evaluation, traceability systems for the food chain with specific reference to animal products and certification of origin for miscellaneous food items. Other factors, not exclusively of scientific nature, like ethical or societal needs are starting to be implemented in the design of experimental protocols, as in the case of ethical protocols design for volunteer studies in the field of nutrition/epidemiology, or replacements of

animals with in-vitro/modelling techniques, in toxicological related studies. In a wider context, the standardisation process should reach the consumer. A good example is functional food, where health authorities have to establish mandatory criteria for the qualification of a functional food product. Functional food should not only be a marketing claim, but rather correspond to well defined scientific criteria.

The following research priorities are grouped according to the proposed structure of FP6 in order to identify the most urgent basic research needs within the single priorities mentioned there[20].

5.1 Safer Production Methods

P21 Development of safer production methods for animal feed

Following the logic developed in chapter 4 "Food Safety and Health", it is important to guarantee high quality input and safety controls at the entrance point of the food chain, the raw material production. This is not only true in the area of crop production, but there is also a clear need for research for safer production of animal feed, to be able for example to understand and manage the Mad Cow Disease.

Scientific efforts are involved in the steady improvement of animal feed in order to enhance animal health and optimise the conversion of feed into milk or meat. These efforts involve the application of quality assurance programmes, using traceability systems along the manufacturing process, and the participation in communication of food safety related aspects. In this respect, the use of animal models will be essential because actual pathogenicity can not be studied outside the intestinal ecosystem yet. However, for ethical and economical reasons, a choice should be made to limit the number of animal trials.

P22 Risk management of new and existing technologies (allergens, emerging pathogens)

When assessing novel conservation technologies, modern analytical tools provide very accurate results. Meanwhile long existing technologies have never been analysed in the same thorough manner because the analytical tools just were not there for the time of introduction. Therefore there is a need for reassessing many existing technologies to verify that they are efficient and safe enough. For example, studies have shown that microwave ovens in some cases do not heat pre-fabricated food to the necessary extent in order to inactivate micro-organisms/pathogens. Another example are mycotoxines staying active in the freezer. This reassessment could also result in an improved use of many techniques. Efficiency may be increased by combining single treatments (already existing/new technologies), to make use of milder parameters for each of the single treatment (e.g.: heat, pressure, radiation technologies; alternative treatments like the use of high electric fields, ultrasound or packaging related techniques; bio preservation/enzymatic

[20] See chapter 2.2, figure 4.

treatments or new additives like ozone). As for food safety, the presence of new emerging food-borne pathogens and the trend to use milder treatments for pathogen inactivation dictates the re-examination of the food safety provided by the existing technologies as well as by the combination of existing and new technologies.

This requires a systematic examination of applied technologies not only in the industrial process chain, but also at the stage of final preparation in restaurants as well as at home. Technology assessment might additionally be an appropriate starting point for increased consumer participation. The risks, but also the benefits of new technologies and new food have to be communicated to the consumer. This encompasses also the communication of the uncertainty related to the application of novel technological solutions.

P23 Updating of hygienic technologies and preservation technologies

Closely related to the previous issue is the need to update existing hygienic technologies, in order to minimise the risk of contamination with chemicals or micro-organisms/pathogens throughout food processing.

Beyond the traditional food preservation methods of thermal processing, freezing, salting and drying, new methods of processing and packaging are emerging (ultra-high pressure hydrostatic processing or pascalisation, ohmic processing, high-intensity light pulses, high electric field pulses, radio-frequency (RF) heating, osmotic dehydration, irradiation, microwave processing, thermo-sonication, modified atmosphere packaging (MAP) and active packaging)[21]. These can extend the shelf-life and freshness of perishable foods.

P24 Understanding interactions of food (ingredients) and processing at the molecular and cellular level

How can we understand better what is happening within the food during food processing, going away from the "cook and look" approach? This deeper knowledge has to include technologies from other disciplines.

Additionally, raw material can be modified in order to improve its properties/performance throughout the single process steps. Consequently, one of the most intensely discussed issues was the need for *increased research at the cellular/molecular level*. According to the experts, new techniques such as genetics and molecular technologies make it possible to *analyse the relation between structure and functionality of food material* and develop on this way a new and deeper understanding. This could be for instance research on the *synthesis and degradation of cell walls*, in order to increase the stress resistance of raw material throughout the post-harvesting/processing/post-processing steps of the food chain, and therefore to maintain a high quality of the food.

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[21] Source: J.T. Barach and R.S. Applebaum "Food technology in the 21st century". Taken from D. Taeymans "New technologies for ensuring the quality, safety and availability of food" , http://www.fao.org/DOCREP/003/X7133M/X7133M04.htm

Research is also required on potential bioactivity of minor proteins of milk, egg, vegetables, cereals and fruits, as well as evaluation of their efficacy in animal model and human clinical studies *per se* and in food systems. The following factors should also be taken into account: Interactions of bioactive proteins with other food components during processing and effects of these interactions on bioactivity, effects of conventional and novel processing technologies on the bioactivity of the proteins, development of novel fractionalisation and purification methods for bioactive proteins and their hydrolysates.

P25 Benefits and risk assessment of new raw materials

Molecular technologies make it furthermore possible to *produce existing raw material with new methods*, by adapting technologies to the raw material and not the other way round. This could help for instance in retaining more nutrients and micro-nutrients through non-thermal inactivation of micro-organisms. Molecular technologies can also open the door to *produce new raw materials with entire new properties*, this corresponds to the already existing trend to design functional food.

In relation to this, it has to be guaranteed that a proper assessment of benefits and risks accompanies the development/production of new raw material. For this assessment, economical, safety and environmental aspects have to be combined. Research has to be carried out to provide the appropriate assessment tools.

5.2 Impact of Food on Health

P26 Gentle processing - generating and maintaining health-promoting quality

Reverse thinking of the food chain - from the plate to the farm – also impacts on applied technologies in food processing. Different developments are under discussion. Food production systems have to be able to deliver fresh food to the consumer, *retaining the quality of the raw material throughout the entire process* to the highest possible extent. One possibility therefore is to minimise processing of food material.

In particular these efforts are devoted to reduce the intensity of the technological damage mechanisms. The result of this effort should be a *gently processed food*, that maintains the quality level that is characterising the raw material. It may be likely that the use of emerging non-thermal technologies may allow the utilisation of novel raw materials, resulting in unique functional foods. Food technologists have to demonstrate that new food products are safe and equivalent to those made by “traditional processes”. This will lead to decisions regarding the selection and use of appropriate technologies. Quantitative risk assessment techniques need to be developed to facilitate the evaluation of microbiological hazards.

The trend of minimal or gentle processing needs the support from a continued basic research in different areas. As heating can destroy sensitive food ingredients, e.g. vitamins, modern pulse heat treatment involves very brief heating interspersed with cooling phases. Air filtration, aseptic packaging and protective atmospheres are used to reduce food spoilage, but freezing still plays a key role. Therefore, current research efforts on changes of nutrients

and texture in foods during cold storage to further optimise freezing processes and product composition are of great importance. Also packaging offers diverse opportunities such as "Active packaging" to enhance freshness characteristics of raw or pre-treated food products, development of visual indicators for thermal stresses for refrigerated/deep frozen products or in the development of new packaging formats adapted to specific consumer segments. A synergetic effect in maintaining food quality and increasing sustainability is obtained by means of packaging technologies (new environmental friendly packaging methods and materials like edible coating/biodegradable films with enhanced barrier characteristics etc.).

P27 Improvement of health generating properties of new food raw materials

In order to provide greater nutritional value and/or higher production efficiency, multi-disciplinary research on the understanding of the genetics and molecular biology of raw materials is necessary. Human metabolism of food, and advantageous or deleterious effects of nutrient balance (e.g. fats, fibre), minor components (e.g. antioxidants), and 'natural' ingredients must better be understood. Further basic research would be required to elucidate the relationship between biochemical and physiological effects and their genetic origins. Maybe methods could be developed to change these by genetic intervention and advanced breeding techniques. Genetic and biochemical change must be related to processability, final product quality and shelflife, and the results of genome studies must be better exploited to make best use of raw materials.

The results of genome studies can be further exploited in order to make best use of raw materials. This supports the aim of ensuring food quality and characteristics from the very beginning, as raw material quality is strictly linked with the genetic potential of grown plants and animals. Biotechnology research, through developing new varieties, holds the potential to enhance the nutritional content of agricultural products and lead to improvements in agricultural techniques, resulting in both increased productivity and reduced environmental impacts along the food chain. Further knowledge on the relationship between plant nutrition and crop yield needs to be developed. One of the objectives will be to understand the significance of biotic (e.g. microbes, brassinosteroids) and abiotic (mineral composition) root-soil interactions for optimal plant nutrition and yield. Anticipated deliverables are deeper knowledge on factors interacting with crop yield, optimised methods to increase crop yield integrating physiological and ecological knowledge and higher crop yield with less pollution risks.

P28 Process design, product design, and information technology

Information technologies have been introduced first in the processing stages of the food chain, for the diffusion of information and control of different processing steps, and later in the raw material production at one end and in the post-processing steps at the other end of the food chain. Development and implementation of bioinformatics may represent, in fact, a powerful tool in the development of genomics, involving a series of potential applications.[22] Traditional ways of product development by trial and error are too time-consuming to meet the demands of the market. Therefore, industry has an increasing need for predictive knowledge. New techniques combined with computer technology can become a predictive power if physical, chemical and biological characteristics of the raw material (such as denaturing temperature, pH dependence, salt and protein concentration, aroma production, etc.) are known, in order to predict the process and product properties (novel cheese production, etc.) The traditional control of the end product is no longer satisfactory. Systems with on-line sensors, in combination with computer simulation programs, will gradually replace quality control systems at the end of the production chain. Environmentally, friendly processes will rise on the priority list of production management, such as savings in energy, water, raw material and waste discharge. Computer models are under development that give insight into process data as well as connect these with product properties.

The utilization of information technologies along the whole food chain in an integrated system may be moreover devoted to offer an actual traceability system in order to go back from the plate to the farm, that is necessary both for safety reasons and for certification of typical products with certified origin. Vertical integration in the food chain (e.g.: poultry meat and dairy sector, infant foods, food products labelled by major distribution food chain) makes it possible to exploit the benefits of information technologies in the most efficient way.

P29 Balancing microbiological flora for health promotion – immunostimulation

This issue refers to the basic research aspect of the question already tackled under the research priority “Immunological system/Bacterial interaction in the colon” in chapter 4.3. It is important not to eliminate entirely microbial activity in food products in order to remove all potential contaminants (“sterile food”), as this includes the risk of decreasing the functioning of the immunological system. Therefore research efforts have to be spent in order to find out what is the appropriate balance of microbiological flora in food products both from a qualitative and a quantitative point of view, and how a fixed level can be stabilised.

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[22] Gene predictions (annotations, small ORFs, peptomics); Organization of genomic data (in individual research groups and in large DBs – DB integration); High throughput image analysis for visual phenotypes; Data processing; Data display; Comparative genomics (maps, sequences); Advanced query tools and data mining techniques; Modeling of biological processing (development, metabolism, pathogen interactions).

5.3 Analysis/Detection of Contaminants and Pathogens

P30 Sensor development (rapid, non-invasive) for detection and analysis/identification of allergens, food contaminants, pathogens, prions, foreign matter, hormones

New molecular technologies might not only be used to enhance properties of raw material and food products, but also for the development of sensors for chemical and microbial contaminants and pathogens. Both for organic and for conventional food products, possible hormones residues, phytohormones and other metabolically active components in food need to be monitored. Another major safety aspect consists in mycotoxines concentration in diet constituents for Mediterranean (e.g.: wine, cereal derivatives and fermented foodstuffs) and for Northern EU countries (beer, cider and bakery products).

The focus in this research issue should be on rapid and selective methods opposite to comprehensive broad range analytical methods. These sensors could be applied in the frame of HACCP systems along the food chain for routine controls, but also to react to emerging food crises, in order to be able to provide quick information on the location and spread of contaminations, and to develop counter strategies.

P31 Detection of non-intentional horizontal genetic material transfer

This research priority refers to horizontal gene transfer related with GMP's (Genetically Modified Plants) field release, with specific reference to gene transfer to related plants, starting from the risk associated with gene flow via outcrossing to sexually compatible plants in ecosystems, or even gene transfer to unrelated organisms e.g.: deriving from the potential for non-sexual exchange of genetic material between organisms belonging to the same or different species. This has to be investigated in detail for newly introduced GMP to make a correct environmental risk assessment possible. This is particularly important when considering the centres of origin and genetic diversity for specific plant species.

5.4 Traceability

P32 Tools and procedures for traceability

Traceability has already been addressed in the framework programme 5 in the Quality of Life and Management of Living Resources Programme, Key Action 1, as a special research target “Quality monitoring and traceability throughout the food chain”. In the meantime, the BSE development as well as other food crises (dioxin in chicken etc.) have shown the outstanding importance of this issue. Therefore research in this area has to be developed further, taking into account on the one hand new insights and discoveries made in the last years, and applying new technologies on the other hand. This should lead to a whole range of new tools, utilising aspects of HACCP systems, Bioinformatics, Proteomics, PCR, DNA micro array techniques, Functional Genomics, Fingerprinting, ELISA methodology (enzyme-linked immunosorbent-assay) etc.

These tools will need the support of appropriate information technologies in order not only to obtain the appropriate information in an efficient manner, but also to create systems which are able to provide the information to food producers and consumers in the appropriate form.

One specific issue which might receive special attention within the research issue *traceability* is the development of information carriers/markers. The technology is available with e.g. radioactive tracers, or resistance markers in the case of trasgenic plants and animals. Especially the latter case is controversial concerning it's long-term effect on human health (related to antibiotics which have been used for transgenics), which makes it even more necessary to develop new information carriers. Also here the use of information technology is needed.

5.5 Environmental Health Risks

P33 Understanding the development of allergens - activation/generation

The traditional approach to food allergy prevention, avoidance of the food allergen, has failed. Food allergens are increasingly becoming a major clinical problem. Both the incidence and severity of allergic diseases are increasing and the age of troubled patients is declining in industrial countries. Approximately 75% of asthma cases are triggered by allergies and the mortality due to asthma have increased considerably over the past 20 years. An increasing number of biotechnology based approaches could be used to solve different food safety issues, including them food allergy. Probiotic administration to infants can decrease allergic symptoms and thus can effectively break the typical progression of allergic symptoms. Thus, further development of rapid tests for allergens and improved process control to minimise contamination of allergens is needed.

New (molecular) technologies should be applied to understand the mechanisms of allergens. Important questions here are the generation of allergens, and how they are activated/deactivated. New insight concerning this relation should be applied directly to the development/design and the improvement of properties of raw materials and food products, in order to avoid new allergenic proteins.

It is also important to understand the threshold of allergenic reaction in sensitive groups. This is important, as there are no zero levels for allergens in food and the knowledge of thresholds allows then to produce allergen-free products even for sensitive groups.

6. Conclusions

The European Food Sector currently finds itself in a state of constant change, caused on the one hand by the need to react to recent food crises, and on the other hand by progresses in technology, bearing risks and opportunities at the same time.

- Amongst the most impacting developments is the progress of biotechnologies during the recent decades. The technological opportunities opened by this development make it now possible to analyse the functionality of food at the molecular level, to create entirely new types of raw material, and to enhance this way the health characteristics of future food products. At the same time, research at the cellular/molecular level can serve to enhance the nutritional value and the health characteristics of foodstuff. The challenge at the European level is to get an overview of the most urgent health problems at the European level, be it obesity or osteoporosis, in order to meet the right demand with new food products.

  The increased understanding of food characteristics at the molecular level will also have repercussions on food processing and post-processing, as it will be possible to better maintain the initial qualities of the raw material downstream through the entire food chain. The development of new food needs to involve the consumers participation from the beginning, in order to avoid problems such as those in the case of GM food.

- A significant pressure on the food sector emerges from a number of food crises, prominent amongst them the BSE appearance in an increasing number of countries, leading to the temporary breakdown of the European market for beef. These crises revealed unmistakably the need for increased research in the area of food safety, e.g. the development of transparent, comprehensive and understandable traceability systems. Traceability is also one of the key factors in the necessary communication to consumers, in order to re-establish trust in the food production systems. Again, the analysis at the cellular and molecular level can help to develop completely new methods and (monitoring) systems in order to improve the safety of food. Thinking for example of HACCP systems with improved IT integration along the food chain, the risk of contamination with chemicals or pathogens can probably be reduced substantially. As large investments in research are needed for the development of such diagnostic systems, a prioritisation has to be made which contaminanats should be tackled first.

- These changes are accompanied by increasing trade flows of food stuff at a global level. This development leads from an economic point of view to a more efficient allocation of food production, but it also generates entirely new problems such as the trade conflicts between the USA and the EU on hormones in beef. Food product trade will grow increasingly important considering the upcoming EU enlargement, bringing not only a whole range of new products and technologies, but also new consumer preferences to the European single market. Being confronted with this increasing and partly unfamiliar product variety in the European food sector, consumer trust has to be maintained through transparent and credible information concerning new foodstuffs and production technologies.

European regulation is responding to these challenges, as an example serve the White Paper on Food Safety and the creation of the European Food Agency EFA. Furthermore, future European research programmes will have to take into account not only the technological development, but increasingly the issues of food (and feed) safety and health and re-establishing consumer trust.

In support of this process, and trying to define some cornerstones for the broader strategy development in the European food sector, this study developed a series of specific research priorities, divided in three different categories:

- Consumer Science
- Food Safety and Health
- Basic Food Science

Within of these categories, subgroups of priorities were used to cluster single research priorities.

Consumer Science

The importance of increased research in the area of consumer science has recently been highlighted through several set-backs to consumer trust. Lost confidence has to be re-established, and therefore new food process and product developments have to include consumer participation/representation from the beginning. The priorities for future research have been split into those issue relevant for the “Consumer behaviour under normal circumstances” and the “Impact of food crises on consumer behaviour”:

CONSUMER SCIENCE

Consumer behaviour under normal circumstances

P1 Determinants of perception of healthiness based on communication and physical product characteristics
P2 Foods designed for special interest groups meeting nutritional, sensory and functional requirements
P3 Labelling
- Labels as credibility signal
- Communication in credibility alliances
- Design of labels based on behavioural science

P4 Traceability from a consumer viewpoint
- Consumer information demand
- Trust
- Differentiation and Segregation

P5 New purchase patterns, information technology and health and safety
P6 Life style and calorie management in the diet
P7 Consumer willingness to pay for increased quality and healthiness
P8 Consumer perception of new food technologies

Impact of food crises on consumer behaviour

P9 Risk perception, information demand and communication in a crisis situation
P10 Analysis of amplification of food crises
P11 Food crisis containment

Food Safety and Health

Consumer trust in the European food sector has been diminished in particular through failures in the area of food safety, with a following risk for or even negative impact on the human health. Therefore re-establishing consumer trust relies essentialy on the notion that food safety and health are priorities, for decision makers in policy as well as in industry.

FOOD SAFETY AND HEALTH

P12 Immunological system/Bacterial interaction in the colon
P13 Bioefficacy understanding - advanced techniques for molecular monitoring
P14 European consolidated epidemiological information, recommendations and priorities
P15 Identify consumer priorities (wishes) for safety & health and develop solution strategies validated by scientific experts
P16 Establish HACCP equivalent methodology for risk assessment to maximise upstream prevention
P17 Develop anticipatory/predictive risk methodology with two main objectives:
- Priorities development
- Preparation of competences and analytical methodology

P18 Availability of healthy food - Resolve technological hurdles:
- Low sensory quality of desirable ingredients
- High cost
- Maintain calorie management: Bulk & Satiety

P19 On-line monitoring techniques, based on molecular tracing: Metabolic risk factors or desirable raw ingredient components (Bioactive molecules)
P20 Investigate Animal – Man/Plant – Man Transferability

Basic Food Science

Many of the identified research priorities in “Basic Food Sciences” address safety and health related issues, which automatically leads to repititions and overlaps with the anterior priorities category “Food Safety and Health”. The fundamental distinction between them are the approach and the time perspective. The main argument underlying the “Basic Food Science” priorities is the need for increased *understanding* of the functionality of food material and its interaction with the human metabolism. Knowledge gained from this research areas is the essential basis to facilitate research as described in the priorities for “Food Safety and Health”.

BASIC FOOD SCIENCE

Safer Production Methods

P21 Development of safer production methods for animal feed
P22 Risk management of new and existing technologies (allergens, emerging pathogens)
P23 Up-dating of hygienic technologies and preservation technologies
P24 Understanding interactions of food (ingredients) and processing at the molecular and cellular level
P25 Benefits and risk assessment of new raw materials

Impact of Food on Health

P26 Gentle processing – generating and maintaining health-promoting quality
P27 Improvement of health generating properties of new food raw materials
P28 Process design, product design, and information technology
P29 Balancing microbiological flora for health promotion – immunostimulation

Analysis/Detection of Contaminants and Pathogens

P30 Sensor development (rapid, non-invasive) for detection and analysis/identification of allergens, food contaminants, pathogens, prions, foreign matter, hormones
P31 Detection of non-intentional horizontal genetic material transfer

Traceability

P32 Tools and procedures for traceability

Environmental Health Risks

P33 Understanding the development of allergens - activation/generation

Despite the categorisation into three main groups, the priorities have two main elements in common: They are strongly oriented towards safety and health, and almost all issues directly or indirectly address consumers concerns.

This corresponds to the probably most important result of the whole activity, the increasing relevance of the socio-economic environment for product and process developments in the food sector. The consumer should be seen as the central element of the food chain and needs to be considered in all development phases of new processes and products. This requires targeted research efforts also from non-technical disciplines, such as behavioural siences. One approach to put the single stages of the food chain into a socio-economic perspective is the here developed re-construction of the food chain from the consumers point of view: The reversed food chain thinking. The main idea behind this approach is to take into consideration the consumer viewpoint from the very beginning when developing new food products and processes, in order to meet the consumer demand to the largest extent possible and to re-establish consumer trust in the European food sector.

Annex -Project Participants

External experts taking part in the Workshops

Dr Dieter **Arnold**, BGVV, Germany,

Dr. Allan **Bradbury**, Kraft Foods Int., Germany,

Dr. Dieter **Cmelka**, Unilever, Germany,

Dr. Huug **de Vries**, ATO Wageningen, The Netherlands,

Dr. Gilles **Fayard**, Nestlé Research Center, Switzerland,

Dr. Katalin **Gara-Nagy**, Europ. Integr. Pollution Prevention and Control Bureau, Spain,

Prof. Klaus G. **Grunert**, the MAPP Centre, The Aarhus School of Business, Denmark,

Prof. W.M.F. **Jongen**, Agricultural University Wageningen, the Netherlands,

Prof. Dietrich **Knorr**, TU-Berlin, Germany,

Dr. Helmut **Koch**, Eridania Béghin-Say, Belgium,

Prof. Nelson **Marmiroli**, Università degli Studi di Parma, Italy,

Dr. Toon **Martens**, Alma Univ. Restaurants Sous Vide Competence Centre, Belgium,

Dr. Thomas **Ohlsson**, Swedish Institute for Food and Biotechnology, Sweden,

Prof. Gunnar **Mogensen**, Chr. Hansen Lab., Denmark,

Dr. Moise **Riboh**, Danone, France,

Prof. Fidel **Toldrá**, Inst. de Agroquímica y Tecnología de Alimientos, Spain,

European Commission

Dr. Anne-Katrin **Bock**, IPTS,

Ms. Susan **Blom**, IPTS,

Mr. Liam **Breslin**, DG RTD,

Dr. Rosemary **Campbell**, IPTS,

Dr. Peter **Eder**,, IPTS

Dr. Karine **Lheureux**, IPTS,

Mrs. Monique **Libeau**, IPTS,

Mr. Hans **Nilsagård**, IPTS,

Mr. Oliver **Wolf**, IPTS,

European Science and Technology Observatory (ESTO)

Dr. Anette **Braun**, VDI, Germany

Dr. Marina **Leonardi**, ENEA, Italy,

Tryfon **Adamidis**, ATLANTIS, Greece

Niels Heine **Kristensen**, DTU, Denmark

Walther **Van Aerschot**, VITO, Belgium