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Tailored Technologies for Future Foods

Report 2001– 2004

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Edited by

Anu Kaukovirta-Norja, Annemari Kuokka
&
Kaisa Poutanen
VTT Biotechnology

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VTT, Vuorimiehentie 5, PL 2000, 02044 VTT
puh. vaihde 020 722 111, faksi 020 722 4374

VTT, Bergsmansvägen 5, PB 2000, 02044 VTT
tel. växel 020 722 111, fax 020 722 4374

VTT Technical Research Centre of Finland, Vuorimiehentie 5, P.O.Box 2000, FI–02044 VTT, Finland
phone internat. +358 20 722 111, fax + 358 20 722 4374

VTT Biotekniikka, Tietotie 2, PL 1500, 02044 VTT
puh. vaihde 020 722 111, faksi 020 722 7071

VTT Bioteknik, Datavägen 2, PB 1500, 02044 VTT
tel. växel 020 722 111, fax 020 722 7071

VTT Biotechnology, Tietotie 2, P.O.Box 1500, FI–02044 VTT, Finland
phone internat. +358 20 722 111, fax +358 20 722 7071

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Keywords enzymatic modification, plant materials, seed factory, encapsulation, microbial viability, food quality, food structure, functionality, sensor quality, consumer expectations

Abstract

This report summarizes the major features and outcome of the VTT research program "Tailored Technologies for Future Foods" (TTFF), conducted in 2001–2004. The program focused on exploiting of biosciences for specific processing and tailored product quality attributes: sensory quality, health effects and safety of food. It also aimed at understanding consumer food choice and the demands for future foods. The program was organised in research teams working on enzymatic modification of food materials, seed factory, microbial viability technology, encapsulation, structure engineering, physiological functionality and consumers and sensory quality.

The total volume of the TTFF Program was 16.2 million EUR. The wide collaboration network covered 18 Finnish university and institute laboratories, and 37 institutions outside Finland. 59 companies and 10 development associations participated in the projects of the program. The research was reported in 185 international scientific publications including reviews and book chapters, and 48 articles in Finnish and 7 articles in trade magazines were published. 8 PhD theses have already been published, 2 more will be defended in 2005 and 3 more in 2006. The total number of theses published during the programme was 24. The number of patents or patent applications was 4.

The report summarises major findings in the seven research teams, and gives 16 result cases. The research on cereal technology included enzymatic tailoring of rye, oat and high-fibre wheat bread baking, process-induced increase of rye bioactivity and design of cereal flavour. Enzymatic structure engineering concepts included search for novel cross-linking enzymes, and their use in proteinaceous food materials. Starch-based microcapsulation aimed at controlling stability of bioactive components. Enzymatic extraction of berry juice and especially phenolic compounds was developed, and berry phenolics were studied as selective inhibitors of the growth of intestinal pathogens. Methods for assessment of digestibility and gut bioconversions *in vitro* were developed. New technology was developed to produce plant-derived compounds in cell cultures, and also to increase and assess viability of probiotic bacteria. Germination was used as a tool to modify seed structure and composition for novel food applications. Consumer perceptions of functional foods was studied as well as perception of troublesome eating among the elderly.

Contents

1. Introduction

The VTT research program “Tailored Technologies for Future Foods” (TTFF) was conducted in 2001–2004. It followed two food-related research programs of VTT, “Minimal Processing” (1996–1999) and “Future Foods” (1997–2000). The TTFF Program continued the VTT approach to exploit biosciences for specific processing and tailored product quality attributes. Focus has been at the use of bioprocessing and combined processes to improve the sensory quality, health effects and safety of food, and to understand consumer food choice and create an understanding of the demands for future foods.

Food consumption will not increase, and the value added is increasingly based on convenience, healthiness and naturalness, that is "service" provided by the manufacturer. The consumer is out for solutions, which the product concepts will have to offer. With safety, cost and palatability at baseline, ease of use and health value are expected to deliver perceived benefits. Biotechnology and bioprocessing are important enabling technologies in future food processing.

The availability of technology is a critical bottleneck for product innovations. Identification and measurement of essential food characteristics are an elementary part of product development. However, also the ability to predict consumer preferences and the application of technologies for design of specific product quality criteria are of increasing importance. The program attempted to address both the demand for new technologies, and that for defining food quality from a consumer perspective.

In the TTFF Program we wanted to increase the internal collaboration at VTT, and expand our research partner network to create new expertise for applications in the food chain. We also wanted the program to be a strategic communication tool both internally and externally. In addition to the accomplishment of research projects, many events were arranged to discuss issues of interest in the program area.

In this report we have summarized the structure and outcome of the TTFF Program: the resources used, the objectives and projects of the 7 research teams, cases of the research results and the publications made.

We thank all the VTT staff for their about 160 person years work input in the program, and the team leaders for their important task of putting it all together. We also wish to thank the wide national and international research and industrial partner network for the fruitful collaboration. Together we can make the science work.

2. TTFF Program

2.1. The outline of the program

The program consisted of 7 expertice teams of which four dealt with the development of generic technology and three more with generic food science. The teams were responsible for the scientific quality, internal and external collaborations and development of project ideas in their fields.

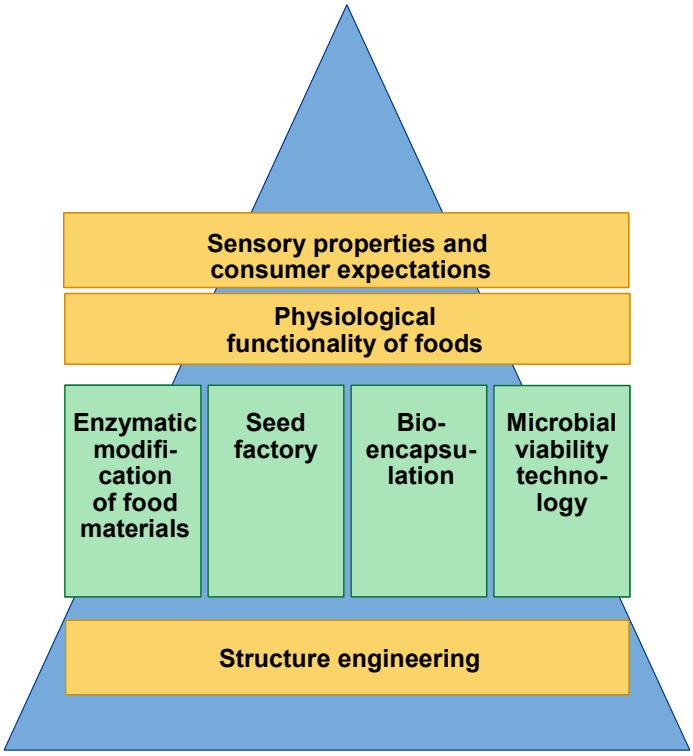

Figure 1. Scientific teams of the TTFF Program.

Team	**Team leader**
1. Structure engineering	Dr. Karin Autio
2. Physiological functionality	Dr. Kirsi-Marja Oksman-Caldentey/ Dr. Riitta Puupponen-Pimiä
3. Consumers and sensory quality	Dr. Liisa Lähteenmäki
4. Enzymatic modification of food materials	Dr. Johanna Buchert
5. Seed factory	Annika Wilhelmson/ Dr. Anna Maria Nuutila
6. Microbial viability technology	Dr. Jaana Mättö/Dr. Liisa Nohynek
7. Encapsulation (years 2001–2002)	Dr. Pirkko Forssell

2.2. Program organization

The program coordinator was Prof. Kaisa Poutanen and the scientific secretary Dr. Anu Kaukovirta-Norja. Dr. Sirpa Karppinen and Ms. Tuija Lyijynen have been responsible for the editing of Platform Newsletters.

The program had two internal management groups:

1) The "Science Forum" consisted of the team leaders (named above), the coordinator and the scientific secretary. It was responsible for the focus of the scientific program, the level of technological and scientific research and the planning of projects.

2) "The Steering Group" decided about the resources at VTT and evaluated the industrial potential of the programme. It consisted of Dr. Johanna Buchert, Dr. Maria Saarela, Dr. Tiina Nakari-Setälä, Prof. Kaisa Poutanen, Prof. Hans Söderlund and Prof. Juha Ahvenainen, with Dr. Anu Kaukovirta-Norja as secretary.

2.3. VTT Food Technology Platform

VTT Food Technology Platform was a communication tool for the research program, informing members about the on-going research by providing selected news about the novel technologies and methods, as well as rapid dissemination of publications and congress presentations.

3. TTFF program: Facts and figures

3.1. TTFF in brief

The total volume of the TTFF Program was 16.2 million EUR during years 2001–2004. In total 65 projects of different size were part of the program.

The funding came from different sources:

- VTT 41 %
- Tekes (Technology Agency of Finland) 32 %
- EU 9.2 %
- companies 8.3 %,
- other sources 9.5 % like Ministry of Agriculture and Forestry, Academy of Finland and Nordic Industry Foundation (NI).

The largest team was the Physiological functionality team with its 22 % share of the resources, followed by the Consumers and sensory quality, the Seed factory and the Microbial viability teams (Figure 2). The Encapsulation team, which was run for the first two years before joining the Structure engineering team, was the smallest one.

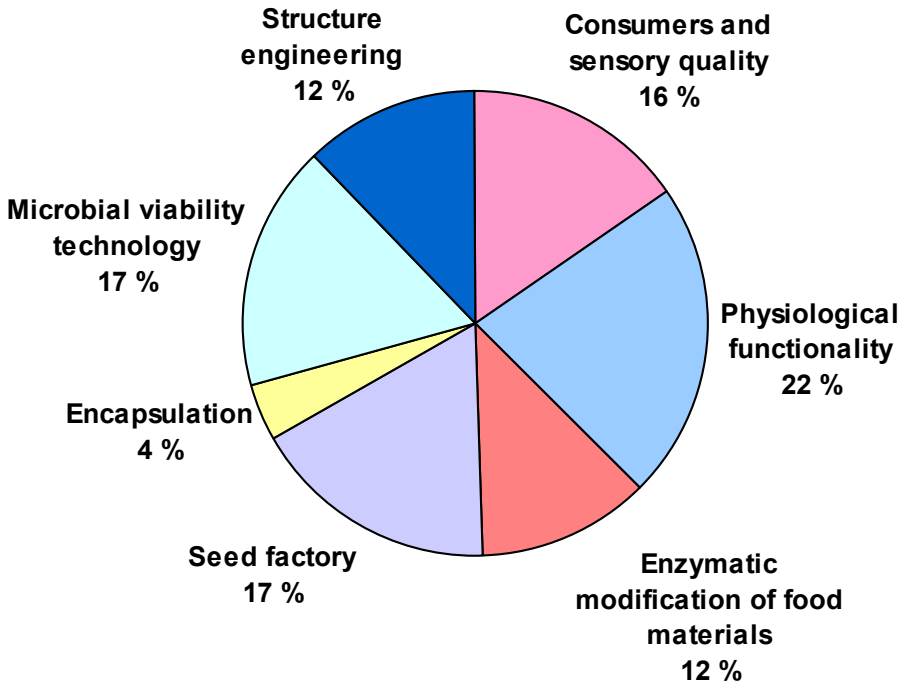

Figure 2. The division of resources between the teams.

The total and annual team volumes are presented in Figure 3.

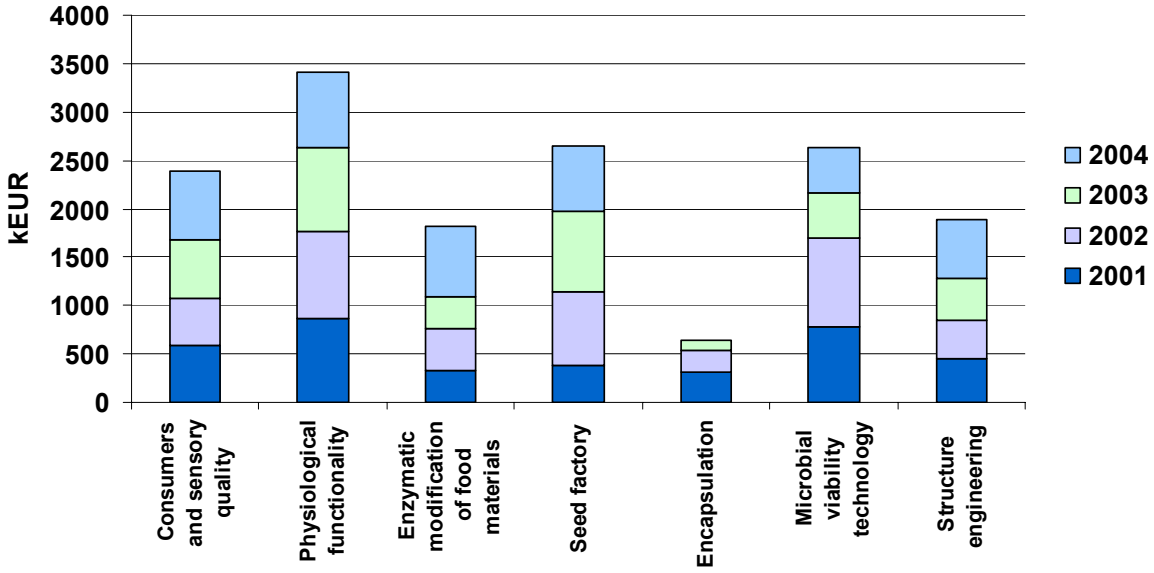

Figure 3. The total and annual volumes of the teams (kEUR).

The total number of international scientific publications including reviews and book chapters was 185. In addition, 48 articles in Finnish and 7 articles in trade magazines were published. 8 PhD theses were published during the program, 2 more will be defended in 2005 and 3 more in 2006. The total number of theses published during the programme was 24. The number of patents or patent applications was 4.

The number of different type of publications and presentations of research teams is presented in Figure 4.

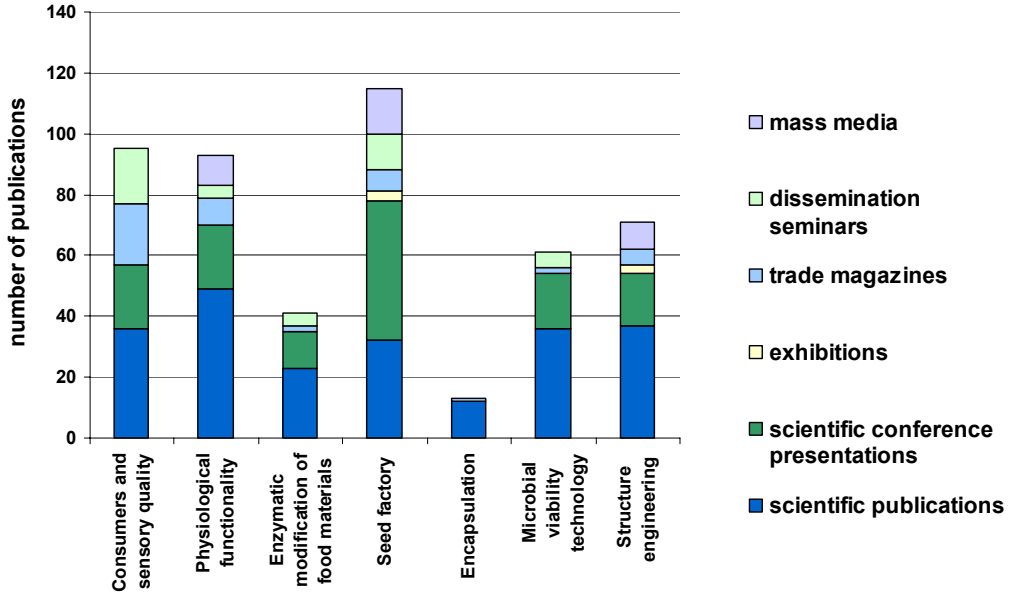

Figure 4. The number of publications and presentations of teams.

3.2. TTFF seminars

Several seminars were organised during the program. The annual seminars were held every spring in Otaniemi, Espoo. One larger national seminar was held in October 2002 and two smaller concentrating on focused topics were held in 2003 and 2004. In addition, the TTFF Program organised for the VTT research staff collaboration meetings with other research institutes and arranged several training and info seminars.

Table 1. TTFF seminars 2001–2005.

SEMINARS 2001–2005		
Date	**Event**	**Target group**
29.3.2001	**Kick-off Seminar**	Start of TTFF, end of FF VTT research staff Companies
21.9.2001	**TTFF Teams**	Team introductions & posters VTT research staff
5.3.2002	**Organic Food Production**	VTT discussion
25.3.2002	**Science citation INFO**	Team members
16.4.2002	**Annual seminar 2002**	Platform members VTT research staff
26.9.2002	**Introduction of Functional Food Centre (Turku)**	VTT research staff
8.10.2002	**How to Stay Healthy in the Future (Biomedicum, Helsinki; in collaboration with Tekes and Duodecim society; in Finnish)**	National seminar and discussion Industry Research Scientists Authorities, Financiers
7.11.2002	**Future road maps seminar**	VTT research staff
10.2.2003	**TTFF Projects financed by VTT**	VTT research staff
12.3.2003	**GMO & Future Foods**	Panel Discussion (semi-open) VTT research staff Research scientists, Authorities Companies Consumer organizations
9.4.2003	**Annual Seminar**	Platform members VTT research staff
14.10.2003	**From research to business: Food industry as a client of VTT**	VTT research staff
26.11.2003	**Research in focus -How do we publish, how are we cited?**	VTT research staff
12.2.2004	**Kuluttajien muuttuvat tarpeet ja elintarvikeketjun kehityshaasteet (The changing needs of consumers and the challenges of the food chain; seminar in Finnish)**	Finnish Food Industry Trade Consumer organisations Research Scientists

SEMINARS 2001–2005		
9.3.2004	**Annual Seminar 2004**	Platform members VTT research staff
3.6.2004	**Enzyme-aided food processing (together with Nordic Innovations Centre)**	Food Industry Research scientists
26.10.2004	**Viikki-VTT Food Science Meeting (in Finnish)**	Collaboration meeting Viikki Food scientists (University of Helsinki) VTT research staff
25.1.2005	**VTT Food Science Day (VTT Elintarviketapahtumapäivä, programme in Finnish)**	Finnish Food Industry VTT research staff

3.3. TTFF network: Research partners and companies

3.3.1. Research partners

One of the targets of the TTFF Program was to catalyse the scientific networking between VTT and other research institutes. The following research partners have been collaboration in the projects of the TTFF Program.

National

Helsinki School of Economics, CKIR

Helsinki University of Technology

- Laboratory of Applied Biochemistry and Microbiology

MTT Agrifood Research Finland

- Chemistry Laboratory
- Food Research
- Plant Production

National Consumer Research Centre of Finland

University of Helsinki

- Faculty of Veterinary Medicine, Department of Basic Veterinary Sciences
- Institute of Biotechnology
- Department of Management and Economics
- Department of Food Technology
- Department of Psychology
- Department of Food Chemistry
- Department of Applied Biology

University of Kuopio

- Department of Clinical Nutrition
- Food and Health Research Centre
- Institute of Applied Biotechnology

University of Turku

- Department of Biochemistry and Food Chemistry
- Institute of Dentistry

International

Agricultural University of Athens, Greece
Biotechnological Institute, Denmark
Campden & Chorleywood Food Research Association, UK
Consejo Superior Investigaciones Cientificas, CSIC, Spain
Eastman Dental Institute, UK
Federeal Research Centre for Nutrition and Food, FRCNF, Germany
French Institute for Agronomy Research, INRA, France
Institute of European Food Studies, IEFS, Ireland
Instituto Tecnológico Agroalimentario, AINIA, Spain
Istituto di Microbiologia Universita di Ancona, Italy
Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione, INRAN, Italy
Istituto Superiore di Sanita, Department of Bacteriology and Medical Mycology, Italy
Joint Research Unit Sciences for Enology, INRA-SPO, France
Leatherhead Food Research Association, UK
Oxford Brookes University, UK
Polytechnical University, Spain
Rothamsted Research, UK
Rowett Research Institute, UK
Swiss Federal Institute of Technology Zurich, ETH, Switzerland
The Royal Veterinary and Agricultural University, Denmark
The Swedish Institute for Food and Biotechnology, SIK, Sweden
Université Claude Bernard Lyon, France
Université Paris Sud, Faculté de Pharmacie, France
University College Cork, Ireland
University of Barcelona, Spain
University of Ghent/VIB, Department of Plant Systems Biology, Belgium
University of Lund, Sweden
University of Murcia, Spain
University of Potsdam & German Institute of Human Nutrition, Germany
University of Surrey, UK
University of Technology, Berlin, Germany
University of Tromsø, IMB, Department of Microbiology and Virology, Norway
Uppsala University, Sweden
Wageningen Centre for Food Sciences, The Netherlands
Wageningen University, Dept of Agrotechnology and Food Science, The Netherlands
Warsaw Agricultural University, Poland
Åarhus School of Business, MAPP, Denmark

3.3.2. Companies

Table 2. The following table includes all the companies which have participated in the TTFF projects.

Finnish Companies	
Alahovin Viinitila Oy	Linseed Protein Finland Oy
Aromtech Oy	Lyckeby Stärkelsen Food & Fibre Ab
Atria Oy	Marli Oy Ab
Bioferme Oy	MP-Maustepalvelu Oy
Biofincon Oy Ab	Nokia
Boreal Kasvinjalostus Oy	Omecol Finland Oy
Borealis Polymers Oy	Orion yhtymä Oyj Noiro
Camelina Oy	Peltohermannin Viinitila
Cloetta Fazer Suklaa Oy	Pharmia Oy
Ediple Oy	Polttimo Yhtiöt Oy
Elisa Oy	Primulan Leipomot Oy
Fazer Leipomot Oy	Raisio Benecol Oy
Finnsonic Oy	Raisio Yhtymä Oyj
FinnSoy Oy	Raitaniemi Star Oy
Gustav Paulig Oy Ab	RavintoRaisio Oy
Hankintatukku Oy	Riekon Marjatila
Hartwall Oy Ab	Riitan Herkku Oy
Helsingin Mylly Oy	Ruokakesko Oy
HK Ruokatalo Oy	Saarioinen Oy
Huhtahyvät Oy	SataMaito
Hämeenlinnan osuusmeijeri	Savon Heat Service Oy
Ingman Foods Oy Ab	Sinebrychoff Oy Ab
Isokaski Oy	Snellman Oy Ab
Jalon Mylly Oy	Suomen Sokeri Oy
Juurespaja Oy Suhoset	Suomen Viljava Oy
Järviseudun Peruna Oy	Suupohjan Marjaosuuskunta
Järvi-Suomen Portti Osuuskunta	Tankki Oy
Karl Fazer Oy Ab	Teriaka Oy
Kemira GrowHow	Trekos Oy
Kesko Oyj	Uimaharjun Leipä Ky
Kymppi-Maukkaat Oy	Vaasan & Vaasan Oy
Laihian Mallas Oy	Valio Oy
Lännen Tehtaat Oyj	Valioravinto Oy Ab
Leaf Oy	Viking Malt Oy
Leipomo Salonen Oy	Vitario Oy
Lieksan Laatuherkut Oy	Åkerlund & Rausing Oy
Linkosuon Leipomo Oy	

International Companies	Development associations, unions
Agralco S. Coop. Ltda	Elintarviketeollisuusliitto
Agrocommerce Innovacion S.A.	ELO-FOOD Pohjois-Karjala
Brauerei Beck & Co.	ELO Varsinais-Suomi
Brauerei Veltins	Foodwest Oy
CEBA Ab	Kotimaiset Kasvikset ry
Cockburn Smithes & Cía. SA	Paahtimoyhdistys
CropDesign	ProAgria
Danisco	Pyhäjärvi-Instituutti
Dansk Procesteknik I/S	Satafood Kehittämisyhdistys ry
Döhler GmbH	Turun ammatti-instituutti
FibroGen	
Findus Ab	
H. J. Fiedler Meeresdelikatessen GmbH	
Ingelhurst Foods	
Meiji Seika Kaisha Ltd	
Miquel Junca SA	
Orafti	
Ringnes Bryggeri	
Scottish Courage	
Sternquell Brauerei Plauen	
Unilever	
Unipress	

3.4. Program evaluations

The TTFF Program together with the previous Future Food Research Program was scientifically evaluated in October 2003. The evaluators were Dr. Francisco A. Tomás Barberán, CSIC Murcia, Spain, Dr. Grete Bertelsen, Royal Veterinary and Agricultural University, Denmark and Dr. Olivier Goniak, Danone Vitapole, France. The evaluation was based on annual reports and additional written materials, access to the intranet web-pages and a two-day visit to VTT with interviews of the scientists.

In general, the programs were evaluated to have raised the scientific and technological skills, which we considered very competitive in Europe. The evaluators expected to see more focus in strategic planning and business-like approach in the future. They suggested that all the research themes should be continued with focus on industry needs and clear definitions of project deliverables already at planning phase.

The national impact of the TTFF Program is being evaluated by Life-Science-Man Ltd (Dr. Anu Harkki) during spring 2005.

4. TTFF teams

4.1. Structure engineering

"Understanding and tailoring the factors defining the food structure."

Food structure is an important quality attribute, since it affects not only the sensory perception of texture, but is also essential for the nutritional properties of foods. The digestibility of starch-based foods can be tailored by influencing microstructure of starch granules with the aid of processing. This knowledge is very important in designing foods with slow glyzemic respound.

VTT Biotechnology focuses on enzyme-aided food structure engineering by developing both enzyme tools (in the team Enzymatic modification of food materials) and enzyme-based applications. Combination of the enzymes with food processing is very challenging, since the optimal conditions for enzyme activity and structure formation may differ greatly, or the enzyme must be added in a step which is not optimal from the point of view of structure formation. We received financing for a new large project "Controlled modification of carbohydrates and proteins", which has enabled us to focus our research as was suggested by the evaluators.

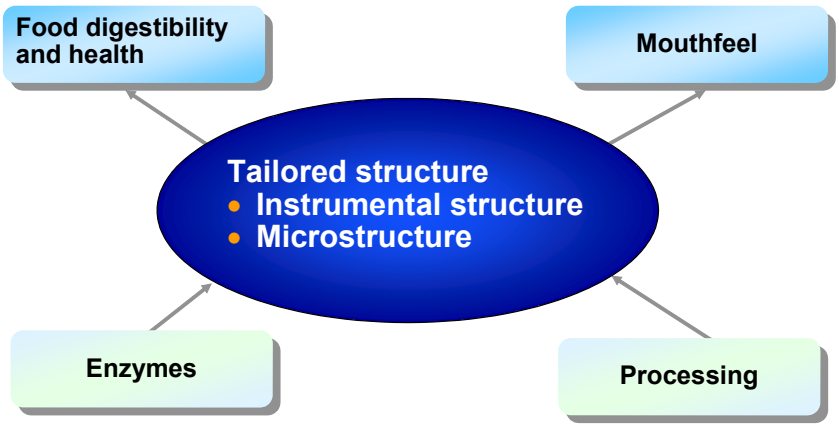

Figure 5. The basic idea of the Structure engineering team.

The two major objectives

- Increase understanding and develop tools for creating structures that have beneficial effects on insulin responses and weight control.
- Develop enzymatic and processing tools that improve the stability and texture of foods.

Table 3. Structure engineering team projects 2001–2004.

Title of the project	Project leader	Duration
Modification of food raw materials with non-hydrolytic enzymes	Raija Lantto	2000–2001
Whole grain oat baking	Marjatta Salmenkallio-Marttila	2001–2002
Wholemeal oat bread	Marjatta Salmenkallio-Marttila	2001–2002
Extrusion: a method for improvement of lipid stability	Pirkko Forssell	2001–2003
Development of whole grain products with low insulin responses	Karin Autio	2001–2004
Oat products, physiological effects	Marjatta Salmenkallio-Marttila	2001–2004
The role of microstructure in the mouthfeel of oat bread	Katariina Roininen	2002
Obesity/Foods for management of weight	Kirsi-Helena Liukkonen	2002–2004
Novel cross-linking enzymes and their consumer acceptance for structure engineering of foods	Johanna Buchert/ Kristiina Kruus	2003–2005
Low-temperature pressure processing of foods: safety and quality aspects, process parameters and consumer acceptance	Martina Lille	2003–2006
Controlled modification of carbohydrates and proteins	Karin Autio	2004–2006

The main results

- We have developed baking methods with cross-linking enzymes and sour doughs for improving the texture, baking quality and nutritional properties of breads. We have developed a new *in vitro testing* method to predict insulin responses of bread. The texture of bread is important property for slowly digestible products. One patent application is under preparation. We have also developed a baking process for wholemeal oat bread which is now in commercial application in a bakery.
- The stability of casein-based structures at normal fermentation temperatures and the texture of meat products have been improved by cross-linking enzymes.
- A method was developed for measuring texture damage caused by freezing and thawing of potato and carrot. The ice crystal damage of starch gels caused by freezing and thawing could be decreased significantly by pressure-shift freezing method at 200–240 MPa.
- We have increased our know-how on the relationship of food microstructure and sensory perception of texture.

Examples of results are illustrated in more detail in cases 5.1, 5.2. and 5.3.

4.2. Physiological functionality

"Know-how and control of factors determining the behaviour of food in the gastrointestinal tract, and development of technologies and innovations for target physiological functions."

Increasing knowledge of the relationship between diet and health leads to new insights into the effects of bioactive food components on physiological conditions and human health. Food products with short and long-term health benefits that promote well-being and reduce the risk of chronic diseases are of great interest to food manufacturers and are highly desired also by modern consumers.

The Physiological Functionality Team aimed to understanding which factors affect the behaviour of nutrients and bioactive compounds of plant-based foods in humans. Special emphasis was directed to increase know-how of the interactions between plant bioactive compounds and human microflora, and of the factors important for glucose metabolism in humans. A lot of expertise has been gained of the behaviour of various plant bioactive components in the gut using *in vitro* models mimicing the gut conditions. The team has also been developing new *in vitro* bioactivity assays and modifying currently used assays to adapt them better for the industrial requirements. Plant secondary metabolites, especially phenolic compounds, but also phytosterols and peptides were studied, as well as dietary fibre, often existing together with phenolic compounds in plants. Development of chemical analysis for characterization of phenolic compounds and their metabolites has been one of the key elements of the research.

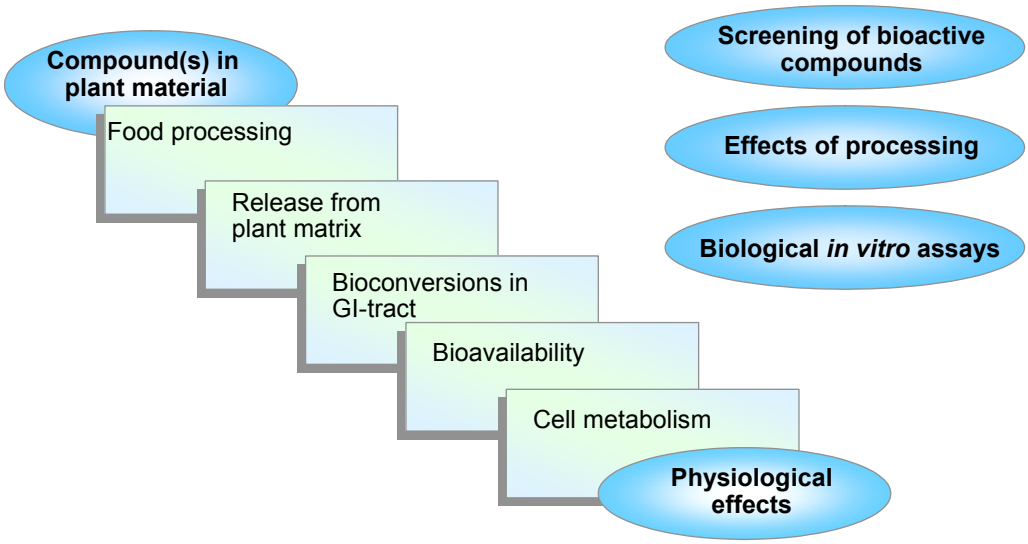

Figure 6. The basic idea of the Physiological functionality team.

Objectives of the team

- Understand better the interactions between bioactive plant components and human microflora – direct and indirect effects.
- Tailor dietary fibre fractions with controlled intestinal fermentation to act in synergy with probiotics and bioactive compounds, especially phenolics.
- Develop further the established *in vitro* models to better suit for industrial needs.
- Understand mechanisms by which antimicrobial phenolic compounds modulate gut microflora.
- Increase knowledge of plants as sources of bioactive peptides.
- Increase analytical knowhow of berry phenolics and peptides.
- Understand the mechanisms by which food structure affects glucose and insulin responses and weight control.

Table 4. Physiological functionality team projects 2001–2004.

The title of the project	Project leader	Duration
Health implications of natural non-nutrient antioxidants (polyphenols): bioavailability and colon carcinogenesis	Anna-Marja Aura	2000–2002
Bioactive compounds in rye: influence on health	Kirsi-Helena Liukkonen	2000–2004
Antioxidative effective foods	Riitta Puupponen-Pimiä	2001–2002
Characterization of plant bioactive peptides	Kirsi-Marja Oksman-Caldentey	2001–2004
Reactions of plant sterols in food and their behaviour in gastro-intestinal tract	Anna-Marja Aura	2001–2004
Non-digestible carbohydrates and lignans in gut-health	Anna-Marja Aura	2001–2004
Metabolism of phenolic compounds of Finnish berries and the effects on gastrointestinal microflora	Riitta Puupponen-Pimiä	2001–2004
Development of whole grain products with low insulin responses	Karin Autio	2001–2004
The effect of probiotics on irritable bowel syndrome and gastrointestinal flora	Jaana Mättö	2001–2004
Effect of phenolic substances and the structure of gel on oral health	Karin Autio	2001–2004
Foods for weight management: effect of structure and composition on satiety and weight control	Kirsi-Helena Liukkonen	2003–2004
Novel enzyme-aided extraction technologies for maximized yield and functionality of bioactive components products and ingredients from by-products	Kaisa Poutanen	2003–2005
Rye bran for health	Kirsi-Helena Liukkonen	2004–2006

The main results

- A lot of knowhow was obtained of antimicrobial effects of bioactive plant compounds and their mechanisms of action against intestinal and oral bacteria. Phenolic berry compounds, such as ellagitannins and anthocyanins, were identified as inhibitory compounds against intestinal pathogens, such as *Staphylococcus* and *Salmonella*. Commercial plant extracts, e.g. green tea extract, inhibited the growth of pathogenic oral bacteria, such as *Streptococcus*. Enzyme treatment of berry material was shown to increase the amount of phenolic compounds and antimicrobial activity.
- Food-plants were shown to contain *in vitro* blood pressure lowering bioactive peptides. Chromatographic fractionation procedure for native peptides present in food-plants was developed.
- Enzymatic *in vitro* digestion method was applied for studying process effects on release of bioactive components from cereal matrices. The profile and concentrations of bioactive compounds in rye could be efficiently modulated by milling fractionation, germination and sour-dough fermentation.
- *In vitro* colon model was applied for pure phenolic compounds and for those within plant matrix. Plant matrix influences the bacterial metabolism of phenolics.
- Particle size distribution of the bread digesta samples correlated well with insulin index.
- Satiety index method can be used to predict the satiating power of individual foods.
- Comparison of intestinal microbiota of subjects suffering from irritable bowel syndrome (IBS) and healthy controls has revealed more instability of intestinal microbiota in IBS subjects than in controls. The instability of the predominant bacteria correlated with instability of clostridia and related bacteria. A subtype of *Bifidobacterium adolescentis* that is more commonly detected in constipation-type IBS subjects than in diarrhoea-type subjects and controls was found.

Examples of results are illustrated in more detail in cases 5.4, 5.5. and 5.6.

4.3. Consumers and sensory quality

"Methods for translating consumer expectations into product attributes and tailoring flavour compounds and microstructure to create flavour quality that fulfils these expectations."

Consumers are becoming increasingly heterogeneous in their wishes when making food choices. For product development this creates demanding challenges. Product development cycles are becoming faster and several demands from different consumer groups needs to de addressed. To support this cycle improved methods to measure consumers' varying expectations and choices, to improve the sensory quality of products and to personalise information according to individual consumer's desires are needed.

Food choices are determined by both rational and affective reasons. Most of the methods used in eliciting food-related concepts are able to elicit the rational and cognitive reasoning consumers use for making choices, but novel methods are required to reach the less consciously acknowledged affective and moral reasons. Consumers make daily choices that have ethical and affect-based connotations: choices are made among conventional, functional, organic, ethnic, low-fat and regular fat products and so on. To better forecast the success of a product in the market entails improved understanding of the mechanisms that influence our food choices.

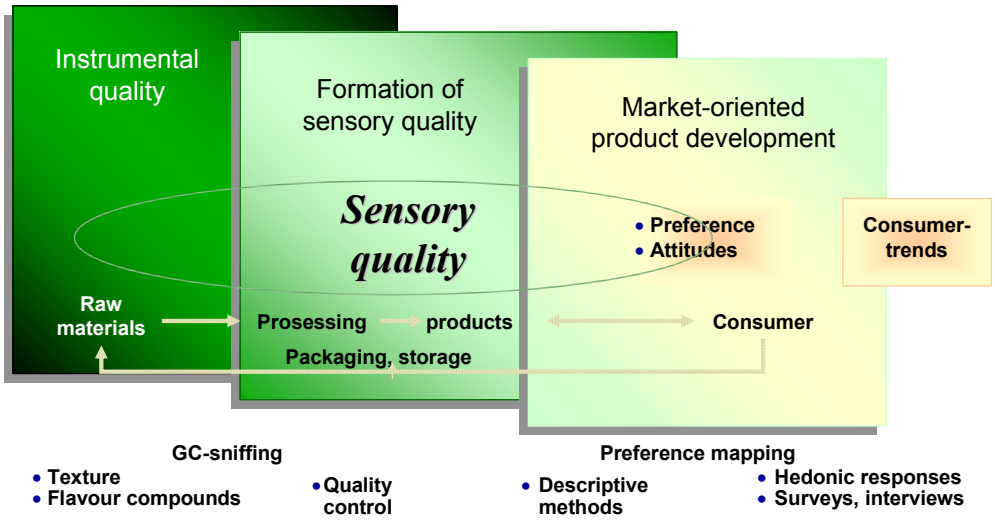

Figure 7. The basic idea of the Consumer attitudes and sensory quality team.

The overall aim was to develop methods that support product development and marketing activities, especially for cereal-based products, functional products and other new products. This includes both improved understanding of how product quality is achieved and perceived, and of the role of health in food choices.

Objectives of the team

- Improve descriptive sensory characterisation of products.
- Improve understanding of the relationships among perceived sensory quality, instrumental measurement of flavour compounds, microstructure, and rheology, and to apply advanced statistical techniques to combine these and consumer data to define the desired target quality.
- Develop more reliable and faster qualitative methods to measure consumers' product related expectations, especially affect-based reasons behind food choices.
- Develop more reliable and faster methods to measure consumers' willingness to make first and repeated choices.
- Develop techniques to convey information to consumers about health-related matters in a personalised and comprehensible way.
- Develop methods to measure product-specific satiety.
- Apply advanced multivariate statistics in analysing consumer responses in studies, including such methods as GLM, factor analysis, PCA, regression modelling, SEMs (structured equation modelling) and conjoint approaches.

Table 5. Consumers and sensory quality team projects.

The title of the project	Project leader	Duration
Monitoring of quality and shelf-life of raw materials and products with electronic nose in food and packaging industry	Raija-Liisa Heiniö	1998–2001
Functional wheat sourdough	Kati Katina	1999–2002
Health claims and acceptability of functional foods	Liisa Lähteenmäki	2000–2001
Healthy ageing: How changes in sensory physiology, sensory psychology and socio-cognitive factors influence food choices	Katariina Roininen/ Liisa Lähteenmäki	2000–2003
Consumer views about processed organic food products	Anne Arvola	2001–2002
Tools for consumer-oriented product development	Liisa Lähteenmäki	2001–2004
Design of foods with improved functionality and superior health effects using cereal beta glucan	Marjatta Salmenkallio-Marttila	2001–2004
Bioactive compounds in rye: influence on sensory quality	Kirsi-Helena Liukkonen	2001–2004
Flavour and texture formation of foods in microwave heating	Raija-Liisa Heiniö	2001–2004
The role of microstructure in the mouthfeel of oat bread	Katariina Roininen/ Tessa Kuuva	2002
Foods for weight management	Kirsi-Helena Liukkonen	2003–2004
Consumer decision making on organic foods	Anne Arvola	2003–2005
Consumers, decision-makers and local or organic food	Katariina Roininen	2003–2005
Situation-based and personalised communication services for distributing product information to consumers	Liisa Lähteenmäki	2003–2005
Enzyme-aided flavour boosting	Raija-Liisa Heiniö	2004–2005

The main results

- The procedures and practices in descriptive sensory methods have been improved by using model samples, panel training, and use of verbal descriptions for attributes in profiling product alternatives.
- Multivariate statistical methods have been applied to combine sensory and instrumental data, and thus improve our understanding of which compounds or other factors influence our sensory perceptions. This approach has enhanced our knowledge about the determinants of sensory quality in cereal-based and microwave-heated products, including both microstructure and the role of volatile compounds in flavour and texture formation.
- Our understanding of what makes vegetables and fruit difficult to eat and how this is related to age has improved.
- New applications to elicit consumers product-related expectations have been developed and compared. Word association provides a quick method and gives a wide range of product specific attributes, whereas with the laddering-method we can obtain also the reasoning behind choices. Repertory grid approach and direct questions on reasons have also been studied.
- Affect- and moral based choice motivations have proved important in consumers decisions on choosing organic foods. The study also applied SEM-modelling in examining the relationships among product beliefs, attitudes and buying intentions.
- An indirect method to measure the impressions consumers create based on shopping behaviour has been developed and applied for consumers of functional food.
- The role of attitudes in choosing functional foods, organic products and towards other types of new foods has been measured and new attitude tools have been developed.
- A choice model to study first and repeated choices has been developed and applied in studying the role of hedonic responses in choice decisions.
- Consumers' wishes and expectations of health-related information have been surveyed and visualisations to convey nutritional messages in a personalised and meaningful way have been developed together with information technologists.
- Methods to measure product-specific satiety have been developed.
- The relative importance of choice reasons in choosing functional foods and products processed or produced with different technologies have been studied by conjoint approach.

Examples of results are illustrated in more detail in cases 5.7, 5.8. and 5.9.

4.4. Enzymatic modification of food materials

"Novel enzyme systems for structure engineering or processing of food raw materials."

Enzymes offer specific means to modify various properties of food raw materials or ingredients. Food is composed basically of biopolymers, which influence the mechanical properties, perceived texture, nutritional value and stability of fabricated foods. Flavour and colour are generally influenced by the lower molecular weight compounds present in the matrix. The chemistry of the biopolymers and lower molecular weight components can be influenced by either added enzymes (exogenous enzymes) or the action of endogenous enzymes present in the food raw material. These changes can subsequently be exploited in improved processes or in products with either added-value or completely new properties.

Due to the rapid development of biotechnological methods, novel enzymes and activity types can be isolated from nature by traditional screening methods or by genome mining. By expressing these genes and/or by purifying the enzymes, the mechanistic and application perspectives of the novel enzymes can be further explored. The full exploitation of the novel biotools in processing requires thorough understanding of the reaction mechanisms involved in both micro- and macroscale. Thus, expertise in protein chemistry, food chemistry, in polymer science and food processing was combined in the team.

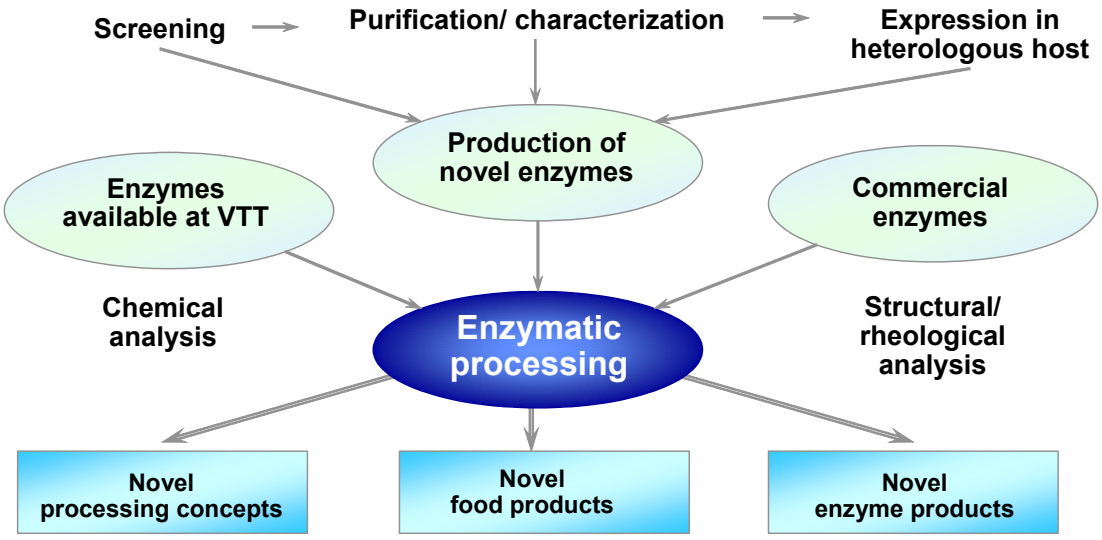

Figure 8. The basic idea of the Enzymatic modification of food materials team.

The enzyme team focused on two main targets:

1. Tailored hydrolysis of plant cell walls in order to improve processability or product quality. Cell-wall degrading enzymes were used to modify the macromolecular structure of the plant material with subsequent increase in the bioavailability or extractability of the valuable components. The main target industrial end-users are berry and vegetable processors as well as companies valorizing or exploiting plant process by-products.

2. Enzyme-aided food structure engineering by developing both enzyme tools and enzyme based applications for e.g. dairy, meat and baking industry. Different crosslinking enzymes were produced and their application potential for crosslinking of food biopolymers is investigated together with the structure engineering team.

Table 6. Enzymatic modifications of plant materials team projects 2001–2004.

Title of the project	Project leader	Duration
Modification of food raw materials with non-hydrolytic enzymes	Raija Lantto	2001
Enzyme-aided extraction of lipid soluble components from plant materials	Annikka Mustranta	2001–2002
New enzymatic peeling methods for vegetables	Marjaana Suutarinen	2001–2003
Control of flavour and texture of foods in microwave heating	Raija-Liisa Heiniö	2001–2004
Characterization of plant bioactive peptides	Kirsi-Marja Oksman-Caldentey	2001–2004
Metabolism of phenolic compounds of Finnish berries and the effects on gastrointestinal microflora	Riitta Puupponen-Pimiä	2001–2004
Flavour and texture formation of foods in microwave heating	Raija-Liisa Heiniö	2001–2004
Engineering of proteinaceous agents as source of physiologically active peptides and food structure modifiers	Tapani Reinikainen	2002
Novel cross-linking enzymes and their consumer acceptance for structure engineering of foods	Johanna Buchert/ Kristiina Kruus	2002–2005
Novel enzyme-aided extraction technologies for maximized yield and functionality of bioactive components of consumer products and ingredients from by-products	Kaisa Poutanen/ Mirja Mokkila	2003–2005
Enzyme-aided flavour boosting	Raija-Liisa Heiniö	2004–2005
Enzyme-aided pressing of value-added berry juices	Annikka Mustranta	2004–2005
Controlled modification of carbohydrates and proteins	Karin Autio	2004–2006

The main results

- Different types of microbial crosslinking enzymes have been screened. Novel fungal tyrosinases have been characterized and produced in large scale after heterologous expression in *Trichoderma reesei.* Advanced analytical tools have been exploited to understand the mechanisms of both existing and novel crosslinking enzymes formation in food systems. Maldi-Tof and Maldi-Tof/Tof MS proved to be excellent tools to identify the types polymers formed in the enzyme catalyzed crosslinking reactions and to determine reactive amino acid side-chains in the peptides. The type of crosslink formed could be further elucidated using FTIR Microscopy.
- The effect of crosslinking enzymes on gel and structure formation of different food proteins and phenolic carbohydrates has been studied. With chicken proteins the efficiency of gel formation catalyzed by tyrosinase increased as a function of enzyme dosage, whereas laccase, generating free radicals to the protein matrix, caused protein degradation when high dosages were applied. Kieffer extensibility rig was exploited in analyzing the rheological changes caused to wheat flour with the crosslinking enzymes. Laccase treatment resulted in dough hardening, whereas xylanase treatment made the dough softer.
- The impact of different cell-wall degrading enzymes on the processing of berry juices and press residues has been investigated. Treatment of berries with commercial pectinolytic enzymes improved the juice yield and the extraction of phenolic compounds from the cell wall materials. The pectinase treatment also increased the total content of anthocyanins in the juices. The effect of enzymes on individual anthocyanins depended on the enzyme preparation used and on the type of anthocyanidin-glycosides present in the berry raw material.

Examples of results are illustrated in more detail in cases 5.1, 5.2, 5.10. and 5.11.

4.5. Seed factory

"Expertise in utilization of germination for new applications, and in modification of the biosynthetic capacity of seeds for novel products."

Seeds store energy for the new plantlet in different forms; e.g. as starch, proteins or lipids. During germination the metabolic activity of the seed is activated and these stored reserves are converted into energy. At the same time the seed synthesizes a variety of compounds necessary for the new plantlet: enzymes, hormones and their precursors. This powerful biochemical machinery of seeds can also be utilized for production of new bioactive compounds or new products for industrial end uses. In Seed Factory the biochemical activity and physiological changes during grain filling and germination were utilized in order to develop novel products and applications. The production of high-value compounds is especially targeted. Furthermore, the ability of cultivated plant cells to produce known or novel bioactive compounds through metabolic engineering is studied, thus enlarging our concept towards plant cell factory.

The research in Seed Factory was focused around two main themes: the regulation of germination for bioactive compounds, and modified seed structure and genetic engineering of seeds and plant cells in general for production of new or known products.

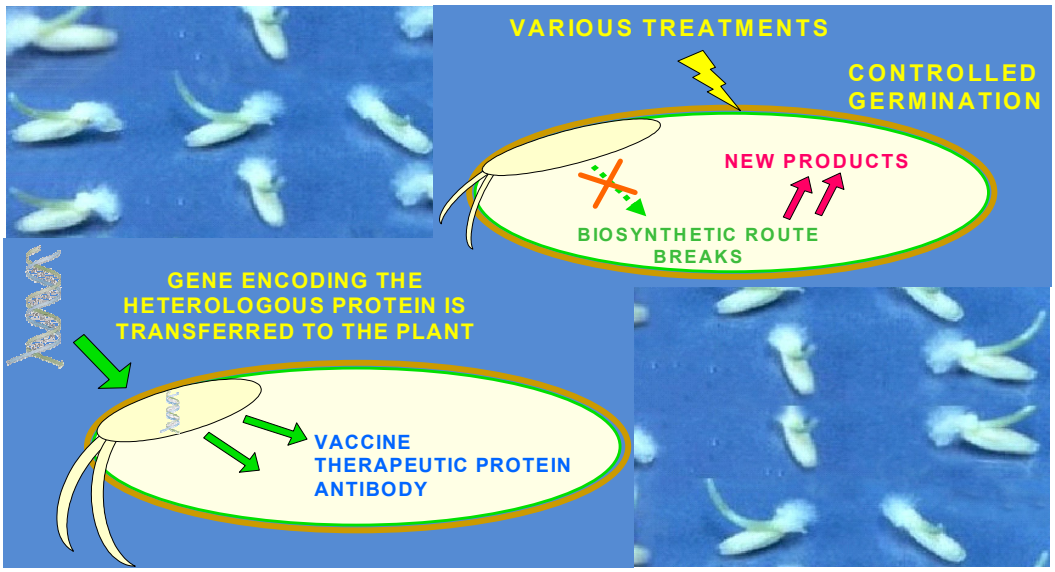

Figure 9. The basic idea of the Seed Factory team.

Objectives of the team

The regulation of germination for modified structure and new products

- The use of germination as a pretreatment for cereals and other seeds to produce a selection of ingredients.
- A deeper understanding of the role of oxygen in seed germination, growth and dormancy breakage, in particular the effect of heterologous haemoglobin expression in barley and Egyptian henbane.
- Understanding the effect of the environment on storage protein localization during grain development and germination.

Genetic engineering of plant cells for production of known or new products

- Combining transcript profiling and targeted metabolomics to understand the genes regulating the biosynthesis of secondary metabolites in plant cells (SOLUCEL® technology).
- Production of transgenic barley plants expressing recombinant gelatin in their seeds under germination and maturation specific promoters.
- Production of non-transgenic oat cell lines from different cultivars in order to evaluate their β-glucan contents. Production of transgenic oat cell lines carrying microbial β-glucan synthase genes.

Table 7. Seed factory team projects 2001–2004.

Title of the project	Project leader	Duration
Application of plant biotechnology in oat improvement	Anna Maria Nuutila	1998–2002
Molecular pharming: Production of an antigenic epitope and monoclonal antibodies against piglet diarrhea in plants	Anna Maria Nuutila	2000–2001
Germinating seed as a bioreactor	Anu Kaukovirta-Norja/ Saara Pöyri/ Annika Wilhelmson	2001–2002
Bioactive compounds of rye	Kirsi-Helena Liukkonen	2001–2003
The influence of oxygen conditions and expression of haemoglobins on breakage of dormancy in seeds	Anna Maria Nuutila	2001–2003
Transgenic raw materials in food production – Detection of transgene and heterologous protein levels	Anna Maria Nuutila/ Anneli Ritala	2001–2003
Production of recombinant gelatin in barley – an alternative production host	Anna Maria Nuutila	2001–2005
A novel approach for the production of pharmaceuticals by plant metabolic engineering	Kirsi-Marja Oksman-Caldentey	2001–2005
The role of polyphenol oxidase in barley	Anna Maria Nuutila/ Annika Wilhelmson	2003
Tailored oat for industrial demands – modern techniques in quality breeding of oat	Anneli Ritala	2003–2006

Heterologous expression of *Vitreoscilla* haemoglobin in germinating seeds and hairy roots	Annika Wilhelmson	2004–2005
Functional oat fractions and their applications	Anu Kaukovirta-Norja	2004–2006
Control of quality risks in malting barley	Annika Wilhelmson	2004–2006
The effect of growth conditions on endosperm structure and storage protein composition in barley (*Hordeum vulgare L.*)	Ulla Holopainen/ Annika Wilhelmson	2004–2006

The main results

- Germination proved to be an effective method for adjusting the flavour of rye. Germination was also found to increase the concentration of several bioactive compounds in many seeds. By combining germination with other processing methods novel types of ingredients can be developed to contribute to the health value of baked foods, beverages and other foods. Furthermore, seeds and seed fractions with improved technological properties and flavour attributes of can be produced for different types of food, feed and other applications.
- A new germination equipment enabling germination under controlled temperature and gas atmosphere was developed. The germination equipment also enables on-line monitoring of volatile metabolites.
- As a step towards a deeper understanding of the oxygen requirement of germinating seeds, barley plants expressing bacterial haemoglobin were produced. Heterologous expression of *Vitreoscilla* hemoglobin had no affect on germination or growth of barley, although barley has a fermentative metabolism during the beginning of germination.
- A novel technology platform SOLUCEL® which is based on functional genomics was developed. This technology allows the improved production of known and novel bioactive compounds in cultivated plant cells with the aid of genetic engineering.
- The method for production of doubled haploid barley (*Hordeum vulgare* L.) through microspore culture was extended to cover transgenic plants and a new barley variety. Also, a method for the production of somatic embryos from alfalfa (*Medicago sativa* L.) cell culture was developed.
- A case study with genetically modified (GM) barley in beer production was carried out. The behaviour of non-GM and GM-barley samples in malting, mashing and brewing were similar. The heterologous protein was detectable from malted GM-grains by immunomicroscopy. Detectable DNA was obtainable from grains, malt and wort, but not from beer. Quantitative PCR was the most reliable method for tracking GM-material and a threshold of 1 part in 1000 (0.1 %) was obtainable with high confidence.

- Within the barley gelatin project, several gene transfer techniques for transient gene expression *in situ* in the seed tissues and in cultured cells were tested and optimised for barley.
- Total of seven transgenic oat lines (*Avena sativa* L.) carrying the BYDV resistance gene have been produced. Three of these lines were used for further analysis. They accumulated variable levels of the transcript RNA, the RNA levels being variable even between siblings of the transgenic lines. This varied RNA expression level was accompanied with very varied BYDV-titers in the early generations of the transgenic plants.
- Transgenic oat callus lines carrying microbial a 1,3-β-glucan synthase gene have been produced.

Examples of results are illustrated in more detail in cases 5.5, 5.7, 5.12. and 5.13.

4.6. Encapsulation

"Encapsulation technologies for plant-based bioactive components using biopolymers as shell materials."

The overall aim was to develop novel microencapsulation technologies for plant based bioactive ingredients and living bacteria using biopolymers as carriers and barriers. The research was focused on development of resistant starch based microencapsulation technology for probiotics and investigations about protection efficiency of starch matrixes for lipid soluble plant extracts.

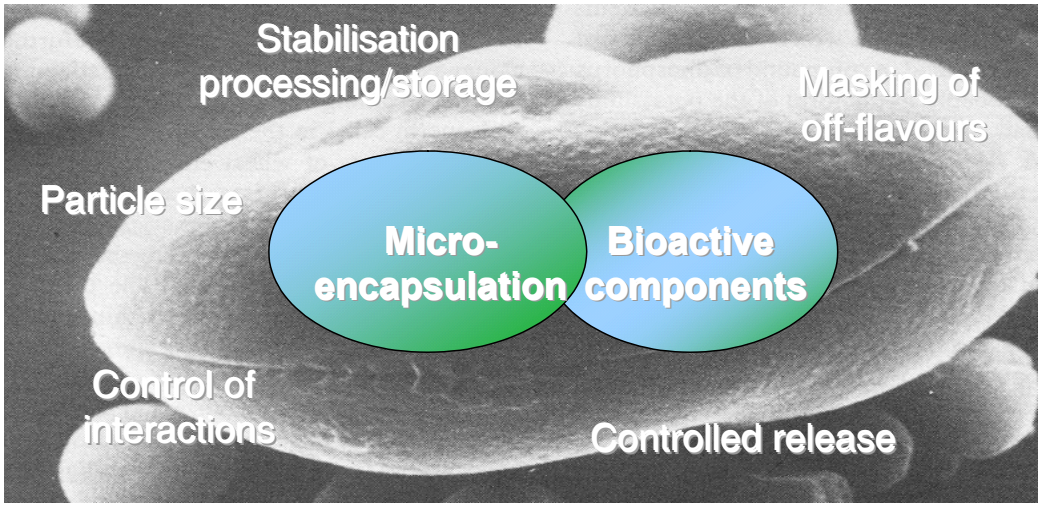

Figure 10. The basic idea of the Encapsulation team.

Objectives of the team

- Investigate effect of relative humidity on storage stability and to enhance water resistivity of microencapsulated probiotics.
- Study release of the microencapsulated probiotics *in vitro* and *in vivo*.
- Elucidate effects of shell material and relative humidity on oxidation stability of microencapsulated oils.
- Learn more about microencapsulation technologies; spray-drying parameters, coating techniques and extrusion.
- Examine behaviour of microencapsulated oils in model systems.
- Understand better the lipid binding properties of starches under extrusion conditions.

Table 8. Encapsulation team projects 2001–2002.

The title of the project	Project leader	Duration
Starch based encapsulation of probiotic	Päivi Myllärinen	1996–2002
Microencapsulation of plant extracts prepared by CO_2	Riitta Partanen/ Piia Hakala	2001–2003
Extrusion, a method for improvement of lipid stability	Pirkko Forssell	2001–2003

The main results

- Starch derivatives, which were used as shell matrix for lipid soluble plant extracts offered protection against oxidation or evaporation under low water activity.
- The obtained results indicate that encapsulation improves the stability of highly volatile compounds against processing at high temperatures, and that encapsulation does not decrease oxidation under moderate or high water activity.
- Potato starch granules in combination with dissolved amylose starch offered a matrix with rather good resistivity against human digestive tract tested by an *in vitro* system. This matrix did not, however, improve the viability of probiotic bacteria at moderate or high humidity.
- Fatty acids in extrusion processed starch were detected to exist as surface lipids, as matrix lipids or as amylose bound lipids. The fatty acids bound with amylose were stable to oxidation but the matrix and surface lipids oxidised, the former especially fast under high water activity.

An example of results is illustrated in more detail in the case 5.14.

4.7. Microbial viability technology

"Molecular and technological tools for control of the viability and stability of bacteria in foods."

Probiotic cultures encounter adverse conditions during production and down-stream processing stages, during formulation and storage, and also during transit through the gastrointestinal (GI) tract. Since it is generally considered that the optimal probiotic functionality is only received with living cultures, probiotic-containing foods and products have to be of good quality to guarantee the delivery of high enough numbers of viable probiotic cells to the consumers.

Microbial viability technology team focused on development and application of technological and molecular tools to control the viability, activity and stability of probiotic bacteria. The developed tools were applied to isolation and characterization of microbes, optimisation of production conditions (fermentation and down-stream processing), as well as evaluation and improvement of activity and stability of added probiotic strains in food products and in the human gastro-intestinal tract. The special emphasis of the team was placed on improvement of probiotic viability and stability in stressful conditions by applying stress adaptation and polysaccharides as carriers and barriers for the cells. Microbial viability and metabolic activity were evaluated by culture-based methods, as well as by molecular and fluorescence techniques.

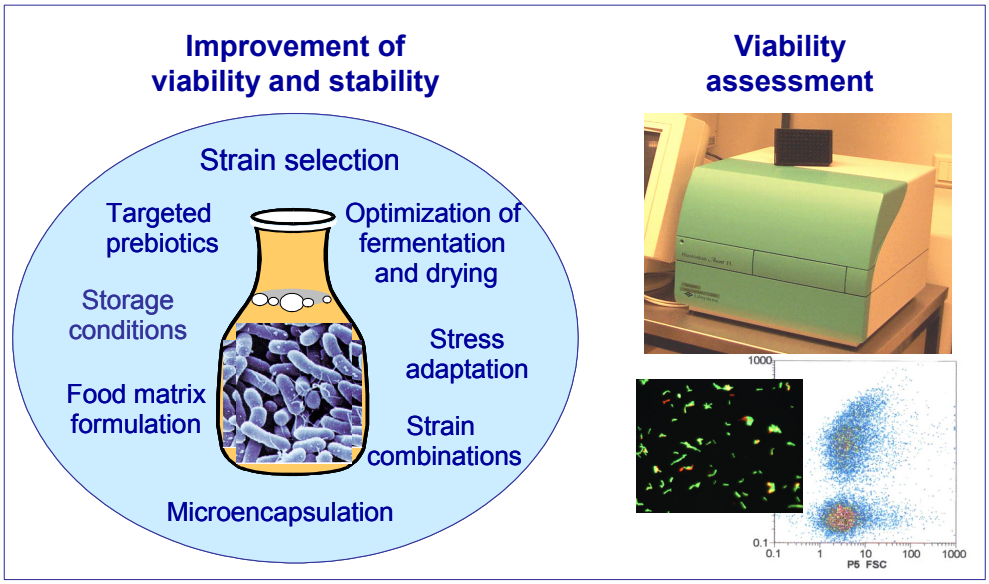

Figure 11. The basic idea of the Microbial viability team.

Objectives of the team

The overall aim was to develop and optimise technologies for improving viability and stability of probiotic cells in adverse conditions and to develop methods for rapid assessment of cell viability and physiology.

- Improvement of viability and stability of probiotic lactobacilli and bifidobacteria using optimised fermentation and down-stream processing conditions, stress treatments and application of fibers and prebiotics as carriers for probiotics.
- Evaluation of probiotic stability in various food matrices and in the GI-tract.
- Development and application of rapid fluorescence techniques for assessment of viability and physiological state of probiotic cells.
- Applying RNA-based techniques for studying composition and activity of human intestinal microbiota.

Table 9. Microbial viability team projects 2001–2004.

Title of the project	Project leader	Duration
Starch based encapsulation of probiotics	Päivi Myllärinen	1996–2002
Control of yeast contamination in food industry	Auli Haikara	2000–2002
Nutritional enhancement of probiotics and prebiotics: technology aspects on microbial viability, stability, functionality and on prebiotic function	Maria Saarela	2000–2004
Development and demonstration of PCR based methods for process control in brewing industry	Auli Haikara	2001–2003
The effect of stress adaptation and capsule technologies on probiotic properties	Jaana Mättö	2001–2004
Metabolism of phenolic compounds of Finnish berries and the effects on gastrointestinal microflora	Riitta Puupponen-Pimiä	2001–2004
Scaling up the process for the production of starch encapsulated microbes	Ilkka Virkajärvi	2002
The effect of GI tract microbiota and probiotics on irritable bowel syndrome	Jaana Mättö	2002–2004
Antimicrobial resistence transfer from and between Gram-positive bacteria of the digestive tract and consequences for virulence	Maria Saarela	2002–2005

The main results

- PDX (polydextrose) and Nutriose FB have proved to be good freeze-drying carriers for *L. rhamnosus* E800 and LGG. Freeze-dried preparations had excellent stability during storage at elevated temperature in powdery form and in oat cereals. Oat fibre showed clearly protective ability during storage of *L. rhamnosus* E800 and LGG cells at room temperature in low pH apple juice. The protective ability of the polysaccharides was not linked to the ability of the strain to adhere to the fiber.
- A new milk-component free fermentation medium was developed for growing probiotic lactobacilli and bifidobacteria. Pilot scale fermentation and down stream processing conditions were optimised for *B. animalis* subp. *lactis*. Under these conditions freeze-dried powders with good storage stability as dry powders and in milk and good tolerance to bile and low pH were produced.
- Viability of probiotics in lethal stress conditions was improved by frementer scale sublethal stress treatment in stationary growth phase. Both stress adaptation and cross protective response was observed in probiotic lactobacilli and bifidobacteria, but the response was highly strain-dependent.
- A rapid microplate-scale fluorescence staining assay proved applicable for evaluation of cell viability of freeze-dried probiotic cells. The assay was also suitable for the assessment of stress tolerance and for the investigation of mechanism of acid tolerance of probiotic bifidobacteria.
- Differences in the fingerprints of faecal microbiota were observed between DNA-based (reflecting the composition of the microbiota) and RNA-based (reflecting the composition and metabolic activity of the microbiota) DGGE analysis. More instability was observed in the DGGE profiles derived from faecal RNA of the irritable bowel syndrome (IBS) subjects than in those of the control subjects, indicating that metabolic activity of intestinal bacteria may vary in IBS patients over time.

Examples of results are illustrated in more detail in cases 5.4, 5.15. and 5.16.

5. Result Cases

The following pages show 16 examples of the results of the TTFF program. These cases illustrate more in detail the type of work conducted in the various themes, and the outcome of the research. They represent the outcome of one or several projects in a specific research topic, and also describe the expected application areas of the results. We hope that some of them are of interest to you and wish you to contact us for more information.

5.1. Enzymes as tools to improve texture of non-wheat cereal breads

Description

Non-wheat flours, such as oat and rye are weak and have poor rheological and baking properties. This is due to the lack of good quality protein and to the high fibre content. Controlled tailoring of biopolymers, i.e. proteins and carbohydrates in the weak flours by exogenic enzymes can be exploited to improve the baking properties and final bread quality. Dough rheology is very important in relation to the quality of bakery products. The extensibility of dough must be good in order to obtain high loaf volumes. Furthermore, the resistance to stretching must be high enough in order to retain the gas in the dough. The suitability of both hydrolytic and crosslinking enzymes on non-wheat baking has been investigated. The viscoelastic and dough handling properties and baking quality of oat flours could be improved greatly by fungal laccase. Laccase increased the number disulfide-bonds in the dough and also increased the molecular weight of oat arabinoxylans.

Expoitation of the results

Enzymatic treatment during baking enables production of good quality products from weaker wheat flours or from non-wheat flours. By using cross-linking enzymes it is possible to improve the dough resistance to stretching, dough handling properties and baking quality of weak flours. A patent application in the dough field is being worked about.

Projects and funding

- Controlled modification of carbohydrates and proteins (COMO), funded by Tekes, VTT and companies, 2004–2007.
- Novel cross-linking enzymes for food structure engineering (CROSSENZ), an EU-RTD -project in the 5th Framework, 2003–2005.
- Whole meal oat baking, MMM, VTT, companies, 2001–2002.

Publications

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- Salmenkallio-Marttila, M., Roininen, K., Lindgren, J.T., Rousu, J., Autio, K. & Lähteenmäki, L. 2004. Applying machine learning methods in studying relationships between mouthfeel and microstructure in oat bread. J. Texture Studies 35, 225–250.

Contacts

Dr. Karin Autio, tel. +358 20 722 5144, karin.autio@vtt.fi.

5.2. Enzymes as tools to improve texture, water-binding and stability of proteinaceous food raw materials

Description

The presence of additional covalent crosslinks in soft gels, such as many dairy products, could prevent post-gelation structural rearrangement and associated syneresis. Since the crosslinks introduced by most of the enzymes are heat-stable, the firmness and elasticity can be retained even after cooking. This offers tools to develop desserts and ready-to-eat foods that can be reheated without structural collapse. The suitability of different crosslinking enzymes to improve the texture of dairy and meat proteins has been investigated. The results obtained depend strongly on the type of enzyme used and also on the accessibility of target amino acids on the respective proteins. Transglutaminase (Tgase) improved drastically the texture of caseinate gels. For 5 % caseinate gel the hardness in the presence of TGase was 4–11 fold and the result could also observed after acidification. This means that Tgase can be used to improve texture in products acidified with microbes. Laccase was found to be suitable for crosslinking of myofibrillar chicken proteins as indicated by SDS-PAGE and rheological measurements.

Exploitation of the results

Crosslinking enzymes provide tools to create structures to dairy or meat products. As the links formed are covalent, the heat stability of the structures is increased. Thus more stable (less phase separation) fermented milk products can be prepared, because the enzymes stabilize the texture at fermentation temperatures generally applied for fermented milk products. Also the texture of meat products containing weak protein has been improved by cross-linking enzymes.

Projects and funding

- Controlled modification of carbohydrates and proteins (COMO), Tekes, VTT, companies, 2004–2007.
- Novel cross-linking enzymes for food structure engineering (CROSSENZ), EU, VTT, 2003–2005.

Publications

- Kuuva, T., Lantto, R., Reinikainen, T., Buchert, J. & Autio, K. 2003. Rheological properties of laccase-induced sugar beet pectin gels. Food Hydrocolloids 17, 679–684.

Contacts

Dr. Karin Autio, tel. +358 20 722 5144, karin.autio@vtt.fi.

5.3. Structure engineering of slowly digestible, "lente" non-wheat breads

Description

The aim was to increase understanding about the role of food structure in glucose and insulin responses and modify structure of wholemeal products in such a way that products with low starch digestibility and low postprandial insulin responses can be manufactured. This type of cereal foods, currently only few available, are considered beneficial in reducing the risk of type 2 diabetes. Postprandial clinical trials were made in University of Kuopio.

A new *in vitro* method based on chewing and stage mimicking stomach has been developed and it has been correlated with insulin responses *in vivo*. The method can be used for predicting insulin responses for wheat and rye breads and the method gives better correlation than the hydrolysis index which does not take into account the gastric emptying time. The results have shown that all rye breads made of 100 % whole meal or white rye flour despite of fibre content give lower insulin responses than white wheat bread in postprandial studies. The low insulin response disappeared when gluten and wheat flour were added to rye flour. Bread hardness was an important determinant of slowly digestible breads.

Exploitation of the results

On the basis of the results we can offer a new *in vitro* testing method to predict the insulin responses of breads. We are developing technological tools, such as cross-linking enzymes and microbes, for tailoring the texture of foods for "lente" applications.

Projects and funding

- Development of whole meal products with low glucose and insulin responses (INSULIINI), Tekes, VTT, Kuopio University, industrial partners.

Publications

- Juntunen, K.S., Laaksonen, D.E., Poutanen, K.S., Niskanen, L.K. & Mykkänen, H.M. 2003. High-fiber rye bread and insulin secretion and sensitivity in healthy postmenopausal women. Am. J. Clin. Nutr. 77, 385–391.
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Contacts

Dr. Karin Autio, tel. +358 20 722 5144, karin.autio@vtt.fi.

5.4. Berry phenolics as selective inhibitors of the growth of intestinal pathogens

Description

Berry phenolics possess many interesting biological activities including antioxidant, anticarcinogenic, antiarthritic and antimicrobial activities. However, interactions between phenolic compounds and gastrointestinal microflora is so far not well understood. Antimicrobial activity of Nordic berries and their phenolic extracts and purified phenolic fractions were measured against human gastrointestinal bacteria including probiotic bacteria and human pathogens. Beneficial lactic acid bacteria were not affected by the berry compounds. However, pathogenic bacterial strains, both Gram-positive and Gram-negative, were selectively inhibited by bioactive berry compounds. Cloudberry and raspberry were the best inhibitors, and *Staphylococcus* and *Salmonella* the most sensitive bacteria. Phenolic compounds, especially ellagitannins, were strong inhibitory compounds against *Staphylococcus* bacteria. *Salmonella* bacteria was only partly inhibited by the berry phenolics, and most of the inhibition seemed to originate from other compounds, such as organic acids. *Listeria* strains were not effected by berry compounds, with the exception of cranberry. Phenolic compounds seem to affect the bacteria in different mechanisms.

Exploitation of the results

Antimicrobial properties of berries could be utilized in functional foods. Furthermore these compounds are of high interest for further evaluation as natural antimicrobial agents for food and pharmaceutical industry.

Projects and funding

- Metabolism of phenolic compounds of Finnish berries and the effects on gastrointestinal microflora 2001–2004 Tekes, VTT, companies.

Publications

- Puupponen-Pimiä, R., Nohynek, L., Meier, C., Kähkönen, M., Heinonen, M., Hopia, A. & Oksman-Caldentey, K.-M. 2001. Antimicrobial properties of phenolic compounds from berries. J. Appl. Microbiol. 90, 494–507.
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Contacts

Dr. Riitta Puupponen-Pimiä, tel. +358 20 722 4457, riitta.puupponen-pimia@vtt.fi.

5.5. Increase of rye bioactivity by processing

Description

The main bioactive compounds in whole grains are vitamins (folates, tocopherols and tocotrienols), phenolic compounds (lignans, phenolic acids, alkylresorcinols), phytosterols and trace elements and minerals. Processing may decrease but also increase the levels of the bioactive compounds in grains, whereas their bioavailability is often increased by processing.

The profile and concentrations of bioactive compounds in rye could be efficiently modulated by milling fractionation, germination and sour-dough fermentation. By milling fractionation, the amount of all the studied bioactive compounds could be concentrated in certain fractions. Germination was an effective pre-treatment for whole grains, producing both improved texture but also elevated levels of bioactive compounds. Combining germination and sour dough fermentation proved the most efficient way to increase bioactivity of whole grain rye: the two processing steps had a synergistic effect in increasing the levels of folates and free phenolic compounds.

Exploitation of the results

The results can be exploited to produce new types of ingredients and cereal foods with improved bioactivity.

Projects and funding

- Bioactive compounds of rye: implications for health effects and flavour (2001–2003 MMM, 2001–2002 Tekes).
- Rye bran for health (2004–2006, MMM).

Publications

- Liukkonen, K.-H., Katina, K., Wilhelmson, A., Myllymäki, O., Lampi, A.-M., Kariluoto, S., Piironen, V., Heinonen, S.-M., Nurmi, T., Adlercreutz, H., Peltoketo, A., Pihlava, J.-M., Hietaniemi, V. & Poutanen, K. 2003. Process-induced changes on bioactive compounds in whole grain rye. Proc. Nutr. Soc. 62, 117–122.
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Contacts

Dr. Kirsi-Helena Liukkonen, tel. +358 20 722 6176, kirsi-helena.liukkonen@vtt.fi.

5.6. Assessment of digestibility and gut bioconversions *in vitro*

Description

The *in vitro* models mimicking human gastrointestinal tract predict reactions of food and bioactive components in physiological conditions. In carbohydrate research our model mimicking the upper intestine has been used for obtaining dietary fibre residues for *in vitro* colon fermentation experiments. In research of dietary phenolics and plant sterols the enzymatic *in vitro* digestion model was applied for the release of dietary compounds from plant matrix and for investigation of structural changes due to the presence of alimentary enzymes and physiological pH. The i*n vitro* fermentation method has been used to study the fermentation rate of carbohydrates and conversion of plant-derived bioactive compounds to their metabolites by colon bacteria.

Exploitation of the results

The models assist food industry to develop process methods for optimal release of components from food matrix in the GI-tract, and give information about the role of gastrointestinal transformations in the metabolism of plant components. The methods offer an extension to chemical analyses in predicting the behaviour of foods & ingredients *in viv*o, and have already been used in several product development projects.

Projects and funding

- Non-digestible carbohydrates and polyphenols in gut health (Tekes 2001–2004).
- Reactions of plant sterols in food and behaviour in the gastrointestinal tract (Tekes 2001–2004).
- Health implications of natural non-nutrient antioxidants (polyphenols): bioavailability and colon carcinogenesis (EU2000–2003).
- Metabolism of phenolic compounds in Finnish berries and their effects on gastrointestinal microflora (Tekes 2001–2004).

Publications

- Aura, A.-M., Kähkönen, M., Vainionpää, M., Heinonen, M., Oksman-Caldentey, K.-M. & Puupponen-Pimiä, R. 2005. Release and detection of berry phenolics in an enzymatic *in vitro* digestion model. J. Agric. Food Chem. Submitted.
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Contacts

Anna-Marja Aura, tel. +358 20 722 6178, anna-marja.aura@vtt.fi.

5.7. Effect of grain processing on cereal flavour formation

Description

High fibre content and other beneficial compounds make whole grain products appropriate for a health promoting diet but their texture and flavour characteristics may require tailoring in aim to gain consumer acceptability. The effects of fractionation, sourdough fermentation and baking, germination and extrusion on sensory quality of oat and rye were studied. Statistical multivariate methods were used to describe how the content of volatile and phenolic compounds are linked with the perceived attributes.

The inner parts of rye grain had a mild flavour, whereas the outer layers with high bioactive activity were bitter in taste. However, a shorts fraction with high level of bioactive compounds and a rye-like but non-bitter flavour was identified. Sourdough fermentation and germination increased the amount of phenolic compounds and increased sourness which could not be removed in heat treatment. Especially the heating step that terminated the germination influenced the levels of flavour compounds. High drying temperature created a roasted, sweet and nutty flavour. The stability improved and oxidation of oat lipids was delayed in germinated and dried oat samples.

Exploitation of results

The results can be utilised by the grain processing industry in developing new tasty and health-promoting whole grain breakfast and snack products and ingredients.

Projects and funding

- Bioactive compounds of rye: implications for health effects and flavour (2001–2003 MMM, VTT 2001–2002 Tekes, VTT, companies).
- Rye bran for health (2004–2006, MMM, VTT, companies).
- Enzyme-aided flavour boosting of rye (2004–2005, Tekes, VTT, companies).

Publications

- Heiniö, R.-L., Oksman-Caldentey, K.-M., Latva-Kala, K., Lehtinen, P. & Poutanen, K. 2001. Effect of drying treatment conditions on the sensory profile of germinated oat. Cereal Chem. 78, 707–714.
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Contacts

Dr. Raija-Liisa Heiniö, tel. +358 20 722 5178, raija-liisa.heinio@vtt.fi.

5.8. Perception of troublesome eating among the elderly

Description

Ageing influences food choices and functioning of senses. Foods that are perceived as pleasant and not too difficult to eat are a prerequisite for a good nutritional status and thereby for good physical condition among the elderly. The objective was to find out how sensitivity varies among the age groups and whether these differences are related to perceived pleasantness of foods.

The role of texture attributes in making foods troublesome to eat, and whether this perceived difficulty is reflected on the willingness to use food products was studied. Often nutritionally wholesome products (vegetables, fruit, meat, cereal-based products) are troublesome to eat and their use may decrease with ageing. Troublesome to eat was related not only to direct texture attributes, such as hardness or hard particles in food, but also to effort required in preparing the food and potential social embarrassment. Based on the results from the project, the practical recommendations on factors that need to be taken account when developing and preparing products for the elderly have been written out for the food industry and caterers. These can help to tailor the mouthfeel and eating quality to suit better the special requirements of the elderly.

Exploitation of results

Recommendations on factors that should be taken into account when designing the products for the elderly were developed and made publicly available. They were also presented to Finnish food and catering industry in December 2003 in an open seminar.

Projects and funding

- HEALTHSENSE. 'Healthy ageing: How changes in sensory physiology, sensory psychology and socio-cognitive factors influence food choices.' (EU, VTT; 2000–2003).

Publications

- Roininen, K., Fillion, L., Kilcast, D. & Lähteenmäki, L. 2004. Exploring difficult textural properties of fruit and vegetables for the elderly in Finland and the United Kingdom. Food Quality Preference 15, 517–530.
- Roininen, K., Fillion, L., Kilcast, D. & Lähteenmäki, L. 2003. Perceived eating difficulties and preferences for various textures of raw and cooked carrots in young and elderly subjects. J. Sensory Studies 18, 437–451.

Contacts

Liisa Lähteenmäki, tel. +358 20 722 5965, liisa.lahteenmaki@vtt.fi.

5.9. Consumer perceptions of functional foods

Description

Functionality represents a new kind of health-related message to consumers. How consumers perceive functionality and functional food products and what kind of impressions people form of users of functional foods were investigated. Functionality gives added value to the product, but all other characteristics in the product need to fulfil the expectations consumers have for that kind of product. The strongest motivation for using functional foods seems to derive from pleasure gained when taking care of oneself. The functionality may also appeal to those consumers who are not keen on traditional nutrition education or conventionally wholesome products. The buyers of functional food products are regarded as innovative consumers.

Exploitation of the results

The research helps to understand what is the meaning of functionality to consumers and improve our understanding of the terms in which functionality gives added value to the products. A public discussion forum on functional foods and consumers was organised with representatives from consumer organisations, retail chains and industry in addition to scientists.

Projects and funding

- Functional foods and acceptability of claims (Ministry of Agriculture and Forestry and VTT, 2000–2001).
- Tools for consumer-oriented product development (TEKES and VTT, 2001–2004).

Publications

- Lyly, M., Soini, E., Leino, U. & Lähteenmäki, L. 2004. Perceived role of fibre in a healthy diet among Finnish consumers. J. Human Nutr. Dietetics 17, 231–239.
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- Urala, N., Arvola, A. & Lähteenmäki, L. 2003. Strength of health-related claims and their perceived advantage. Int. J. Food Sci. and Technol. 38, 815–826.
- Urala, N. & Lähteenmäki, L. 2004. Attitudes behind consumers' willingness to use functional foods. Food Quality Preference, 15, 793–803.

Contacts

Liisa Lähteenmäki, tel. +358 20 722 5965, liisa.lahteenmaki@vtt.fi.

5.10. Novel crosslinking enzymes for food applications

Description

Novel crosslinking enzymes were screened from different culture collections and by using genome mining. Target activities have been lipoxygenase, transglutaminase-type enzymes and tyrosinase. The screening procedure resulted in discovery of several potential crosslinking enzymes. The genes encoding most potential enzymes were isolated, and expression systems for their production constructed. The mode of action of the enzymes on both chemical and macromolecular levels is being assessed. The enzymes were shown to be able to crosslink different types of food proteins, such as casein and myofibrillar protein, resulting in gel formation. The strength of the gel was dependent on the reaction conditions used.

Exploitation of the results

The novel enzymes identified are currently being patented. The major aim is to obtain a product patent enabling industrial manufacture of a novel enzyme by an enzyme company. The enzyme product can subsequently be exploited for food structure engineering concepts in dairy, baking, meat etc. applications.

Projects and funding

- Novel crosslinking enzymes and their consumer acceptance for structure engineering of foods (CROSSENZ). EU-funded RTD -project in the 5th Framework programme.

Contacts

Dr. Johanna Buchert, tel. +358 20 722 5146, johanna.buchert@vtt.fi.

5.11. Identification of most suitable enzyme profiles for production of different types of berry juices

Description

Several commercial pectinase-based products are currently in the market and exploited by berry processing industry to facilitate pressing. The key enzyme in improving the juice yield is pectinase combined with other endo-acting cell wall degrading enzymes. The commercial enzymes also contain significant amounts of side activities, which potentially can hydrolyze anthocyanins to the corresponding instable aglycons. Thus, thorough understanding of the enzyme activities is needed in order to be able to select the most beneficial product to the industrial berry juice production. Activity profiling of a wide variety of commercial pectinases was carried out and analysis of the impact of different side activities on anthocyanin extractability and stability was determined with different berries. The activity profiling was carried out using standardised biochemical enzyme activity assays with model substrates. The following activities were measured: endoglucanase, mannanase, xylanase, β-glucanase, endopolygalacturonase, pectin methylesterase, β-glucosidase, β-galactosidase and α- arabinosidase. Depending on the berry used, the presence of β-glucosidase, β-galactosidase or α- arabinosidase were detrimental to the anthocyanin stability. Thus, by calculating the relative activities of these enzymes to polygalacturonase content, the most beneficial enzyme preparation could be selected to each raw material.

Exploitation of the results

Berry processors can exploit the methods when selecting the most appropriate enzyme preparation for their process. As anthocyanins are important both with respect to biological activity and also to colour of berry products, it is essential to be able to select enzymes which effectively liberate them from berry matrix, but also prevent the formation of labile aglycones.

Projects and funding

- Novel enzyme-aided extraction technologies for maximized yield and functionality of bioactive components of consumer products and ingredients from by-products (MAXFUN), an EU-funded RTD-project belonging to the 5th framework Programme.
- A national research project entitled “Enzyme-aided pressing of value-added berry juices” (ENZMARJA) funded by the Ministry of Agriculture, VTT and industrial companies.

Publications

- Buchert, J., Koponen, J.M., Suutarinen, M., Mustranta, A., Lille, M., Törrönen, R. & Poutanen, K. Effect of enzyme-aided pressing on anthocyanin yield and profiles in bilberry and black currant juices. J. Sci. Food Agric. Accepted.

Contacts

Dr. Annikka Mustranta, tel. +358 20 722 5144, annikka.mustranta@vtt.fi.

5.12. Germination as a tool to modify seed structure and composition for novel food applications

Description

The knowledge and technology bases on the studies of barley malt and the malting process carried out at VTT Biotechnology for decades. The germination projects have focused on the structural changes of the seeds leading to new technological properties, and the modification of the seed composition, especially the production of bioactive metabolites in seeds. The germinated seeds have included oat, rye, wheat, turnip rape, flax and lupin, and various positive changes in bioactivity, structure and flavour have been obtained. A special technology has been created for germination of flax seeds.

Exploitation of the results

By combining germination with other processing methods novel types of ingredients can be developed to contribute to the health value of baked foods, beverages and other foods. Furthermore, seeds and seed fractions with improved technological properties and flavour attributes of can be produced for different types of food, feed and other applications.

Projects and funding

- Germinating seed as a bioreactor (2001–2002, VTT).
- Novel bioactive rye products by processing and cultivar selection (2001–2003, Tekes, MMM, VTT, companies).
- Functional oat fractions and their applications (2004–2006, MMM, VTT, MTT, companies).

Publications

- Heiniö, R.-L., Katina, K., Wilhelmson, A., Myllymäki, O., Rajamäki, T., Latva-Kala, K., Liukkonen, K.-H. & Poutanen, K. 2003. Relationship between sensory perception and flavour-active volatile compounds of germinated, sourdough fermented and native rye following the extrusion process. Lebensm.-Wiss. u. -Technol. 36, 533–545.
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Contacts

Dr. Anu Kaukovirta-Norja, tel. +358 20 722 7117, anu.kaukovirta-norja@vtt.fi.

5.13. SOLUCEL® – A new technology to produce plant-derived compounds in cell cultures

Description

A number of known and novel pharmaceuticals are of plant origin, and they belong to the highly complex and diverse group of plant secondary metabolites. Plant extracts and pure compounds are used in large quantities in functional foods. A rational engineering of plant biosynthetic pathways to increase the contents of secondary metabolites requires a thorough knowledge of the whole pathway, and a detailed understanding of the regulatory mechanisms controlling the flux. Such information is not yet available for the vast majority of secondary metabolites, explaining why only limited success has been obtained by metabolic engineering.

VTT Biotechnology and VIB Plant Systems Biology (Ghent, Belgium) have jointly explored and further developed a novel technology platform based on functional genomics to produce high-value compounds in cultivated plant cells. The proof-of-concept was obtained in a model plant, tobacco. We were able to build an ample inventory of genes, either known or novel, potentially involved in alkaloid metabolism and possibly in plant secondary metabolism in general. Later this technology was applied to two valuable medicinal plants. High-throughput methods for functional analysis of hundreds of candidate genes involved in plant secondary metabolism were developed.

Exploitation of the results

This technology offers an alternative production system for high-value compounds in cultivated cells, the chemical synthesis of which is difficult. Currently these compounds still have to be isolated uneconomically from the plants. Furthermore by metabolic engineering it is possible to get completely new bioactive molecules which are not present in the intact plant.

Two patent applications have been filed and scientific results have been published in high impact factor journals. SOLUCEL® technology can be applied by pharmaceutical, food, biotechnical and cosmetic industries. Negotiations are currently going on with several industrial partners. VTT aims establishing a spin-off company based on this technology during 2005.

Projects and funding

- A novel approach for the production of pharmaceuticals by plant metabolic engineering (2001–2005). Funding from VTT, Tekes NeoBio program, ABS Graduate School and EU Marie Curie Programme.

Publications

- Goossens, A., Häkkinen, S.T., Laakso, I., Seppänen-Laakso, T., Biondi, S., De Sutter, V., Lammertyn, F., Nuutila, A.M., Söderlund, H., Zabeau, M., Inzé, D. & Oksman-Caldentey, K.-M. 2003. A functional genomics approach toward the understanding of secondary metabolism in plant cells. Proc. Natl. Acad. Sci. USA 100, 8595–8600.
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Contacts

Dr. Kirsi-Marja Oksman-Caldentey, tel. +358 20 722 4459, kirsi-marja.oksman@vtt.fi.

5.14. Controlling stability of lipid soluble bioactive components by starch-based microcapsules

Description

Incorporation of bioactive compounds into foods and cosmetics to develop health-promoting and other new products is a challenging task, as the effective components are often sensitive to oxygen, light and/or water. Microencapsulation can be used to form a protective wall around the active core or to form a matrix, in which the active agent is dispersed. The microencapsulation project focused on starch derivatives and their capability to protect oils rich in unsaturated acids from oxidation and oil soluble volatiles from evaporation. The technology applied to produce microcapsules was spray-drying. Oxidative stability of the matrix depended heavily on environmental humidity, which was observed when microencapsulated sea buckthorn seed oil was stored under controlled humidity and at constant temperature for several months. Under dry conditions the microcapsules were stable but at moderate or high humidity oxidation of the oil occurred. The release of the volatile caraway extract from similar matrices was also very slow under dry conditions (at 70^{o}C). Furthermore the rate of oxidation depended on starch derivative forming the matrix, which was linked with differences in the glass transition temperature of the matrix. Relating these results with our earlier observation of oxygen permeability across starch films – dramatic increase above water content 20 % when the film matrix was in rubbery state – it can be concluded that oxygen and most likely also volatile diffusion in the matrix is the most critical factor controlling the protective efficiency of the matrix.

Exploitation of the results

The results demonstrate that the protective effect of commercial starch derivative coatings is restricted to moderate humidity conditions. The knowledge gained is a solid basis for further development of protective biomaterial carriers. The understanding of critical factors controlling the oxygen and volatile transport in starch-based matrix can as well be applied generally when solving food matrix stability problems where oxygen and water are the key players.

Project and funding

- Microencapsulation of plant extract prepared by supercritical CO_2 (2000–2002). Funding from Tekes, VTT and companies.

Publications

- Partanen, R., Ahro, M., Hakala, M., Kallio, H. & Forssell, P. 2002. Microencapsulation of caraway extract in β-cyclodextrin and modified starches. Eur. Food Res. Technol. 214, 242–247.
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Contacts

Dr. Pirkko Forssell, tel. +358 20 722 5212, pirkko.forssell@vtt.fi.

5.15. Improvement of viability of probiotics by fermenter-scale stress treatments and by using fibers and prebiotics as carriers

Description

The applicability of stress adaptation and various carriers in enhancing the viability of probiotics in adverse conditions was studied. Probiotic *Lactobacillus* spp. and *Bifidobacterium* spp. strains were treated in sublethal stress conditions followed by the assessment of tolerance to conditions mimicking the GI-tract or low pH food products. The protective effect of fibres and prebiotics during freeze-drying and storage (as freeze-dried preparations, and in low pH apple juice and breakfast cereals) was evaluated for two *Lactobacillus rhamnosus* strains showing different abilities to adhere to fiber preparations. To mimic the industrial-scale production of probiotics, cells were grown in fermenters using food-grade components and the treatments were performed at a stationary growth phase. Both technologies used for protecting the cells in adverse conditions were promising. Stress tolerance (mainly tolerance to otherwise lethal pH) of each strain could be improved by inducing stress response at a stationary growth phase. However, the suitable conditions (pH and/or temperature) need to be tailor-made for each probiotic strain. Although large differences in the protective abilities were detected between different fibers and prebiotics, promising carriers for both probiotic *L. rhamnosus* strains were found. Polydextrose and wheat dextran were good freeze-drying carriers showing excellent storage stability both as freeze-dried preparations and in dry food matrices, while oat fiber with high β-glucan content showed protective ability in low pH apple juice.

Exploitation of the results

Stress treatment approach can be utilized by manufacturers of probiotics to improve the viability of the bacteria in down-stream processing (e.g. using spray-drying as an alternative for freeze-drying), during storage in food matrices (e.g. low pH juices or at elevated temperatures) and during gastric transit. The strain-carrier combinations reveal promising opportunities for the development of synbiotic products in food matrices which are currently rarely used in probiotic applications.

Projects and funding

- Nutritional enhancement of probiotics and prebiotics: Technology aspects on microbial viability, stability, functionality and on prebiotic function; PROTECH (2000–2004; EU and VTT).
- The effect of stress adaptation and encapsulation technologies on probiotic properties; STRESSIPROB (2000–2004; Tekes and VTT).

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Contacts

Dr. Maria Saarela, tel. +358 20 722 4466, maria.saarela@vtt.fi.

5.16. Development of microplate fluorometer assay for assessment of viability of probiotic bacteria

Description

Viability assessment of probiotic bacteria is traditionally performed by plate count technique. In addition fluorometric techniques have been developed for the detection of viable, injured and dead bacterial populations. In these techniques epifluorescence microscopy or flow cytometer have been used for the detection. The aim of this study was to develop a rapid microplate assay for the viability assessment of stressed and non-stressed probiotic cells.

The microplate scale fluorochrome staining assay proved to be applicable for viability assessment of fresh and freeze-dried probiotic lactobacilli and bifidobacteria. The assay was also suitable for the evaluation of stress tolerance and for the investigation of mechanism of acid tolerance of a probiotic *Bifidobacterium* strain.

Exploitation of the results

The type of assay developed allows rapid detection of cell viability in probiotic products, and is a promising tool for the assessment of viability in studies involving large number of samples. Applicability of the technique for the detection of probiotic viability in food matrices needs to be assessed.

Projects and funding

- Nutritional enhancement of probiotics and prebiotics: Technology aspects on microbial viability, stability, functionality and on prebiotic function; PROTECH (2000–2004; EU and VTT).

Publications

- Alakomi, H.-L., Mättö, J., Virkajärvi, I. & Saarela, M. Application of microplate scale fluorochrome staining assay for assessment of viability of probiotic preparations. J. Microbiol. Meth. In press.
- Maukonen, J., Alakomi, H., Nohynek, L., Hallamaa, K., Leppämäki, S., Laitila, A., Mättö, J., Mattila-Sandholm, T. & Saarela, M. 2005. Viability of probiotic bacteria in non-dairy drinks and in pharmaceutical products as assessed by fluorescence techniques and by culture. Revised version submitted.

Contacts

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Tailored Technologies for Future Foods
Report 2001–2004

Abstract

This report summarizes the major features and outcome of the VTT research program "Tailored Technologies for Future Foods" (TTFF), conducted in 2001–2004. The program focused on exploiting of biosciences for specific processing and tailored product quality attributes: sensory quality, health effects and safety of food. It also aimed at understanding consumer food choice and the demands for future foods. The program was organised in research teams working on enzymatic modification of food materials, seed factory, microbial viability technology, encapsulation, structure engineering, physiological functionality and consumers and sensory quality.

The total volume of the TTFF Program was 16.2 million EUR. The wide collaboration network covered 18 Finnish university and institute laboratories, and 37 institutions outside Finland. 59 companies and 10 development associations participated in the projects of the program. The research was reported in 185 international scientific publications including reviews and book chapters, and 48 articles in Finnish and 7 articles in trade magazines were published. 8 PhD theses have already been published, 2 more will be defended in 2005 and 3 more in 2006. The total number of theses published during the programme was 24. The number of patents or patent applications was 4.

The report summarises major findings in the seven research teams, and gives 16 result cases. The research on cereal technology included enzymatic tailoring of rye, oat and high-fibre wheat bread baking, process-induced increase of rye bioactivity and design of cereal flavour. Enzymatic structure engineering concepts included search for novel cross-linking enzymes, and their use in proteinaceous food materials. Starch-based microcapsulation aimed at controlling stability of bioactive components. Enzymatic extraction of berry juice and especially phenolic compounds was developed, and berry phenolics were studied as selective inhibitors of the growth of intestinal pathogens. Methods for assessment of digestibility and gut bioconversions *in vitro* were developed. New technology was developed to produce plant-derived compounds in cell cultures, and also to increase and assess viability of probiotic bacteria. Germination was used as a tool to modify seed structure and composition for novel food applications. Consumer perceptions of functional foods was studied as well as perception of troublesome eating among the elderly.

Keywords
enzymatic modification, plant materials, seed factory, encapsulation, microbial viability, food quality, food structure, functionality, sensor quality, consumer expectations

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