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VTT research programme on Minimal Processing Final report



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Keywords food, processing, quality, shelf life, thermal treatment, minimization, packaging, high pressure technology, coating technology, VTT

Abstract

At the beginning of 1996 VTT Biotechnology started a four-year VTT Research Programme 'Minimal Processing of Foods'. In this programme new, mild, inexpensive and natural methods to improve the shelf-life and safety of foods were to be developed. The aims of the programme were to improve the sensory quality, nutritional properties and safety and increase the competitiveness of food products based on domestic raw materials.

A total of 18 different projects were carried out in the Research Programme. Twelve projects involved research cooperation with other national or international research institutes and companies. The main topics were minimization of heat processes, development of active packaging films and improvement of the shelf-life of fresh foods. The most important technologies studied were high pressure technology, supercritical extraction, sous-vide cooking, novel gas packaging methods and materials, coating technology, utilization of protective cultures and application of nisin and other natural compounds such as organic acids, and combined methods (hurdle technology). Furthermore, the potential of various novel physical (e.g. light pulses, electric field pulses, ultrasound) and chemical methods (e.g. mustard oil, lactobionic acid, ozone) for food preservation were preliminarily surveyed.

Strategically important in the Programme was that novel methods were studied for real and relevant foodstuffs and food raw materials, and in quality and shelf-life studies both microbiological as well as sensory quality (appearance, flavour, texture) were considered. Most of the available information in the scientific literature deals with the effects of novel methods in laboratory media, or the effects have been studied only to a limited extent, ignoring e.g. the sensory evaluation of the flavour of treated food.

The Programme considerably increased knowledge of the possibilities of various novel process and packaging technologies to minimize the harmful effects of processes on the sensory and nutritional quality of food without microbiological safety risks. Optimized processes and recipes, combined methods and integrated approaches were found to be the most promising ways to maintain the quality and ensure the safety of foodstuffs. The significance of quality management from the field to the table or from raw material production to the consumer was emphasized in the Programme. The basics for development of active packaging materials were also created in the programme. Coating

technology appeared also to have promising possibilities as a 'precision weapon' in many applications, but still needs further development. High pressure technology will have potential in some special, gourmet food products to ensure shelf-life, but also needs further development. Other novel physical and chemical methods will be promising for ensuring microbial safety and for modification of the texture of food products.

In Finland, experimental design or predictive microbiology have hitherto been used very little in product development in the food industry. Improved procedures for optimization of processes and packages were developed in the Programme. Experimental design (e.g. surface response methodology) is an essential tool for optimization. Furthermore, process and recipe improvement is always a multi-stage procedure, in which e.g. computer-based programmes on predictive microbiology will help to reduce the number of experiments and to determine the optimal range of processing temperature and time or recipe conditions. In the Programme, this working approach was launched particularly for the meat and sous-vide industry.

The minimal processing concept, as such, was also developed during the programme. It was clearly realized that the concept supports the idea of sustainable development and the imago of health-promoting properties of foodstuffs. From the legislative point of view minimal processing might even be an easier way to develop health-promoting foodstuffs than the approach in which health-promoting compounds are added to the food product. Some companies adopted the concept in their strategy concerning product and process development. They also simplified and optimized their processes. Public awareness about the advantages of minimal processing approach was also increased. Standardisation and legislation are important elements in the development of the minimal processing concept. The Programme took part in the EU FAIR Concerted Action CT96-1020 project 'Harmonization of safety criteria for minimally processed foods'. Recommendations and possible methodologies for standardisation of safety criteria were given in the project.

Dissemination of the results of the projects was an essential part of the Programme. The total number of research reports from the projects of the Programme is over one hundred. Some of them are non-public. In addition to these, three annual reports and one report on a trade mark were prepared from the Programme. Altogether 26 original scientific papers have been prepared from the results of the various projects of the Programme. Furthermore, 38 professional publications in international and national magazines have been published. Eighteen invited lectures and 19 scientific posters have been delivered. The amount of other publications (monographs, lectures, processing guides, chapters in books etc.) to date is 44. In addition, one patent application on the pre-treatment of strawberries for freezing and one training video on the treatment of fresh strawberries have been prepared. Six national and seven international seminars were organised entirely or partly by the Minimal Processing Programme.

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Tiivistelmä

Vuoden 1996 alussa VTT Biotekniikka käynnisti 4-vuotisen tutkimusohjelman 'Elintarvikkeiden Minimal Processing'. Ohjelmassa kehitettiin uusia, keveitä, edullisia ja luonnollisia menetelmiä elintarvikkeiden säilyvyyden ja turvallisuuden parantamiseksi. Ohjelman tavoitteina oli parantaa kotimaisista raaka-aineista tehtyjen elintarvikkeiden aistittavaa laatua, ravitsemuksellisia ominaisuuksia ja turvallisuutta sekä niiden kilpailukykyä. Ohjelmassa toteutettiin yhteensä 18 projektia. Kaksitoista niistä oli yhteistyöprojekteja joko kansallisten tai kansainvälisten tutkimuslaitosten ja yritysten kanssa. Projektien pääaiheina olivat lämpöprosessien minimointi, aktiivisten pakkauskalvojen kehittäminen ja tuoretuotteiden säilyvyyden parantaminen. Tärkeimmät tutkitut tekniikat olivat korkeapainetekniikka, ylikriittinen uutto, sous-vide-kypsennys, uudet kaasupakkausmenetelmät ja -materiaalit, päällystysteknologia, suojaviljelmien, nisiinin ja muiden luonnollisten yhdisteiden kuten orgaanisten happojen käyttö sekä yhdistelmätekniikat (ns. hurdle effect). Lisäksi alustavasti arvioitiin muutamien uusien fysikaalisten (esim. valopulssit, sähköpulssit, ultraääni) ja kemiallisten (esim. sinappiöljy, laktobionihappo, otsoni) menetelmien mahdollisuuksia elintarvikkeiden säilytyksessä.

Keskeistä ohjelmassa oli se, että uusia menetelmiä kokeiltiin todellisille elintarvikkeille ja elintarvikeraaka-aineille ja elintarvikkeiden laatua tarkasteltiin kokonaisvaltaisesti ottamalla huomioon aistittavan laadun kaikki puolet ja mikrobiologinen säilyvyys. Suurin osa saatavilla olevasta tieteellisestä kirjallisuudesta, joka koskee uusien menetelmien vaikutuksia mm. mikrobeihin on tehty laboratorioalustoilla tai sitten menetelmän vaikutusta on tutkittu hyvin rajatusti, unohtaen esim. aistittava laatu. Siten kirjallisuudessa esitetyt tulokset ovat useimmiten liian lupaavia; aine tai menetelmä, joka toimii laboratorio-olosuhteissa ei välttämättä toimikaan enää todellisessa elintarvikkeessa. Tämä havaittiin mm. nisiinin suhteen.

Ohjelma lisäsi huomattavasti tietämystä uusien prosessi- ja pakkaustekniikoiden mahdollisuuksista vähentää prosessien haitallisia vaikutuksia elintarvikkeiden aistittavaan ja ravitsemukselliseen laatuun ilman mikrobiologisia riskejä. Optimoidut prosessit ja reseptit, yhdistelmätekniikat ja kokonaisvaltainen laadunhallinta pelloilta (alkutuotannosta) pöytäan osoittautuivat parhaimmiksi tavoiksi ylläpitää elintarvikkeiden laatua ja

varmistaa niiden turvallisuus. Ohjelmassa luotiin myös perusteet aktiivisten pakkausmateriaalien kehittämiseksi. Päälystysteknologia osoittautui lupaavaksi ns. 'täsmäaseena' monissa sovelluksissa, mutta se tarvitsee vielä käytännön kehitystyötä. Korkeapainetekniikalla on mahdollisuuksia erikois- ja herkkuelintarvikkeitten valmistamiseksi, mutta sekin tarvitsee vielä tutkimusta. Muut uudet fysikaaliset ja kemialliset menetelmät ovat lupaavia mikrobiologisen turvallisuuden varmistamiseen ja elintarvikkeiden rakenteen muokkaukseen.

Suomessa koesuunnittelua ja ennustavaa mikrobiologiaa on tähän mennessä käytetty hyvin vähän elintarviketeollisuudessa. Ohjelmassa luotiinkin parantuneet menettelytavat prosessien ja pakkausten optimoimiseksi. Tietokonepohjaiset koesuunnittelumenetelmät ovat oleellinen osa optimointia. Prosessien ja reseptien parantaminen on aina monivaiheista, jolloin tietokonepohjaiset ennustavan mikrobiologian ohjelmat auttavat vähentämään kokeitten määrää ja määrittämään oikean alueen prosessointilämpötilalle ja -ajalle sekä reseptille. Ohjelmassa uudet menettelytavat lanseerattiin mm. lihateollisuuteen ja sous-vide-tuotteita valmistaviin yrityksiin.

Minimal processing -käsite kehittyi myös ohjelman aikana. Minimal processing -ajattelu tukee kestäväää kehitystä ja terveysvaikutteisten elintarvikkeiden imagoa. Lainsäädännölliseltä kannalta minimal processing saattaa olla helpompi tapa kehittää terveysvaikutteisia elintarvikkeita kuin menettelytapa, jossa terveysvaikutteista yhdistettä lisätään elintarvikkeeseen. Eräät yritykset lanseerasivat käsitteen tuotekehityksensä strategiaan ohjelman kuluessa. Nämä yritykset myös yksinkertaistivat ja optimoivat prosessejaan. Myös yleinen tietoisuus minimal processingin eduista lisääntyi.

Standardointi ja lainsäädäntö olivat myös tärkeitä tekijöitä minimal processingin kehittämisessä. Ohjelma otti osaa EU-projektiin CT96-1020 project 'Harmonization of safety criteria for minimally processed foods'. Projektissa annettiin suositukset ja mahdolliset menettelytavat minimaalisesti prosessoitujen elintarvikkeiden turvallisuuskriteerien standardoimiseksi EU:ssa.

Syntyneitten tulosten levittäminen oli olennainen osa ohjelmaa. Ohjelman projekteista kirjoitettiin yli sata joko julkista tai ei-julkista tutkimusraporttia projektien rahoittajille ja yhteistyökumppaneille. Itse ohjelmasta valmistui johtoryhmälle 3 vuosiraporttia ja raportti tavaramerkistä. Tähän mennessä on myös valmistunut yhteensä 26 tieteellistä alkuperäisartikkelia tai opinnäytetyötä, 1 patenttihakemus, 38 ammatillista julkaisua sekä kansainvälisissä että kansallisissa lehdissä ja 44 muuta julkaisua, kuten prosessioppaita sekä yksi opetusvideo. Lisäksi on pidetty 18 kutsuttua esitelmää ja esitetty 19 posteria eri tilaisuuksissa. Ohjelma oli myös joko täysin tai osittain vastuussa kuuden kansallisen ja seitsemän kansainvälisen seminaarin järjestämisestä.

Preface

At the beginning of 1996 the four-year VTT Research Programme 'Minimal Processing of Foods' was started. In this programme new, mild, inexpensive and natural methods to improve the shelf-life and safety of foods were to be developed.

The programme was coordinated by VTT Biotechnology. About 40 % of the financing was covered by VTT budget funding and the rest was obtained from various public funding organisations and private companies, which is gratefully acknowledged. Both national and international research co-operation was an essential part of the programme. Several projects of the Programme belonged to National Technology Agency (Tekes) Research Programmes or to the EU-FAIR Programme. The Unit also took part in the Nordic network project 'Minimal Processing - Preservation Methods of the Future'. The authors warmly thank all the partner in Finland and in foreign countries.

The Programme was steered by a management committee, the chairman of which was Professor Juha Ahvenainen from VTT Biotechnology. Other members of the management committee were Mr. Jari Kauppila, MSc, Tekes, Mr. Jukka Salminiitty, MSc, Tekes, Research Director Juhani Hvitfelt, Lännen Tehtaat Oy, Director Mirja Rautakoski, Saarioinen Oy (1996–1997), Quality Director Maarit Kyyrö, Saarioinen Oy (1998–1999), Director Jouko Tikkanen, Kotimaiset Kasvikset ry (1996–1998), Research Scientist Päivi Jämsen, Kotimaiset Kasvikset ry (1999), Director Raimo Hautala, Suomen Kalakauppiaaliitto (1996–1998), Director Asta Nousiainen, Suomen Kalakauppiaaliitto (1998–1999), Research Professor Tiina Mattila-Sandholm, VTT Biotechnology and Research Professor Kaisa Poutanen, VTT Biotechnology. The support as well as the contribution of the members of the management committee is gratefully acknowledged.

The authors also extend their warmest thanks to each and everyone who contributed to the Programme at VTT.

August 2000

Raija Ahvenainen
Manager of the Research Programme

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APPENDICES 1–18

1. INTRODUCTION

The preservation and quality of foods have always been important to consumers. Furthermore, consumers in industrially developed countries are increasingly demanding foods that have "fresh-like qualities" and are convenient, but retain a good shelf-life. These demands have led food companies to further develop traditional methods and also to find new preservation methods that cause minimal adverse changes in foods, yet offer desirable benefits derived from an increased shelf-life. This approach has become known as "minimal processing of foods".

Research on minimal processing started at VTT Biotechnology at the end of 1980s with the use of protective cultures and minimal processing of vegetables (pre-peeled and fresh-cut produces) (Skyttä *et al.* 1993, Raaska & Mattila-Sandholm 1995, Ahvenainen & Hurme 1995, Ahvenainen 1996, Skyttä *et al.* 1996). Optimization of food cooking processes and packaging, novel mild processing methods and development of active and smart packaging were other areas of special emphasis in research on minimal processing already in the early 1990s (Myllymäki & Kervinen 1995, Kervinen & Henriksson 1996, Randell *et al.* 1995). In the years 1994, 1995 and 1996 VTT Biotechnology also organised, in cooperation with SIK, Gothenburg, three symposia on different aspects on minimal processing, with many industrial participants (Ahvenainen *et al.* 1994, Ahvenainen *et al.* 1995 and Ohlsson *et al.* 1996).

At about the same time the concept of minimal processing started to develop. Minimal Processing is the mildest possible preservation technique tailored to a particular raw material and food. The aim is to maintain natural properties of a foodstuff by non-obtrusive processing using a minimum of preservatives. Very soon it was also realized that preservation methods in the minimal processing of foods can basically be classified into three different categories:

1. Optimized traditional preservation methods (e.g. canning, blanching, freezing, drying and fermentation) in order to improve quality and to save energy.
2. Novel mild preservation techniques, such as high-pressure technology, electric field pulses (so-called non-thermal processing), various mild heat treatments, sous-vide cooking, post harvest technologies, protective microbiological treatment etc.
3. Combinations of various methods and techniques (hurdle-effect), whereby a synergistic effect is obtained.

It was also realized that very short shelf-life products need preservation methods that will prolong the shelf-life, whereas long shelf-life products need methods that give improved sensory and nutritional quality even with shorter shelf-life .

On the other hand, it was recognized that microbiological safety might be challenged by using the minimal processing concept, particularly in the case of chilled foods. Traditionally, in addition to refrigeration, decreased pH and lowered a_w are commonly used as hurdles for preservation of microbiological quality of chilled foods. For example, in order to prevent the risks caused by *Clostridium botulinum* in chilled foods to be stored over 10 days, current recommendations include chilled storage combined with either:

1. minimum heat treatment of 90 °C for 10 minutes or equivalent;
2. pH of 5 or less throughout the food;
3. salt level of 3.5 % (aqueous) throughout the food;
4. a_w of 0.97 or less throughout a food or
5. any combination of heat and preservative factors which has been shown to prevent growth or toxin production by *C. botulinum* (Betts 1996).

However, deliberate use of any single hurdle is only limited to a small range of products due to off-flavour effects. If the aim is to keep food products in a fresh-like state, the last mentioned factors (5) are the only possibilities to increase shelf-life and ensure microbiological safety. New mild processing and packaging methods should be developed, current methods should be optimised and their synergistic effects should be determined in order to meet the specific acceptance criteria of consumers, otherwise the products cannot be marketed successfully and without microbiological risks.

At the beginning of 1996 VTT Biotechnology started a four-year VTT Research Programme 'Minimal Processing of Foods'. In this programme new, mild, inexpensive and natural methods to improve the shelf-life and safety of high-quality food products based on vegetables, berries, fish and meat were to be developed. The aims of the programme were to improve the sensory quality, nutritional properties and safety and increase the competitiveness of food products based on domestic raw materials. The aim was also to improve the level of know-how of the institute on minimal processing, particularly on combined methods.

The most important sub-aims of the Programme were:

- Discovery of mild, physical methods for preservation and modification of foods.
- Improvement of tenderization of meat by physical methods.
- Discovery of mild, natural preservatives for meat and fish products.
- Expansion of the range of practical applications of the bacteriocin nisin.
- Improvement of microbiological safety of meat and fish products, mainly by decreasing the risk caused by *Clostridium botulinum*.
- Decreasing the sodium content in meat and fish products.
- Substitution of sulphites in the prevention of enzymatic browning of pre-peeled potatoes.
- Improvement of the post-harvest quality of fresh strawberries.
- Improvement of the texture of strawberry-based jams.
- To obtain information concerning the possibilities of novel gas packaging and active packaging methods for preservation of meat products, fish and vegetables (good microbial quality, low respiration)
- Minimization of packaging by edible coating and antibacterial packaging materials.
- Evaluation of commercially available computer-based predictive microbiology programmes for risk assessment.
- Provision of a sound scientific base for the setting of standards and regulations relating to the safe production and distribution of minimally processed foods in the EU.
- The initiation of product development projects with food companies and research projects in the EU.

2. IMPLEMENTATION

The programme was mainly implemented through projects covering three different areas: minimization of heat processes, development of active packaging films and improvement of shelf-life of fresh foods. Furthermore, dissemination of the results of the projects was an essential part of the Programme. Six national and seven international seminars were organised entirely or partly by the Minimal Processing Programme.

2.1 Projects

Altogether, 18 projects were carried out in the Research programme (see Table 1, page 6 and Appendices 1–18.). The objectives, main achievements, profit made from the achievements, further research needs and prospects and dissemination of the results of each project have been presented in detail in the Appendices 1–18.

Furthermore, the programme had connections with the following EU-projects: COST915 Action 'Consumer - oriented quality improvement of fruit and vegetables', coordinated by Prof. Wim Jongen, Wageningen University, the Netherlands (the Finnish coordinator was Dr. Raija Ahvenainen), EU-FAIR CT96-1175 project 'Combined high pressure thermal treatment of foods: A kinetic approach to safety and quality evaluation' coordinated by Prof. Marc Hendrickx, Catholic University Leuven, Belgium (the Finnish coordinator was Dr. Karin Autio) and the thematic network project 'HI - Innovation in Horticultural Products' (Innovative practices and technology transfer in the chains of fresh and minimally processed fruits and vegetables) coordinated by Sociedade Portuguesa de Inovacao, Porto, Portugal (coordinated in Finland by Dr. Raija Ahvenainen). In the EU-FAIR CT96-1175 project the institute invested in a laboratory-scale high pressure equipment suitable for kinetic studies as well as for product development (Fig. 1).

2.2 Technologies

Several technologies and techniques were studied and applied to various kinds of food raw materials and food products according to Table 2. Furthermore, an integrated approach starting from raw materials and their handling and extending to the market was adopted in the projects 2, 3, 4, 8, 11, 12, 13, 14, 15 and 16.

Table 1. The projects carried out in the VTT Research Programme Minimal Processing.

Minimization of heat processes for foods

1. Food applications of high pressure technology
2. Development of marination of meat¹
3. Development of manufacturing techniques for meat products with low sodium content¹
4. Optimization and safety of sous-vide cooking¹
5. Novel processing and cooking methods for the food industry¹
6. EU-FAIR GT95-1148: Development and practical implementation of novel combinations of nisin with other biopreservatives and mild processes that expand the range of application of the bacteriocin in assuring food safety and quality (NISINPLUS)
7. The texture and shelf-life of berry jams
8. Enhancement of the industrial use of Finnish strawberries

Development of active packaging films

9. Antibacterial packaging materials
10. Active, edible films and coatings²

Improvement of shelf-life of fresh food products

11. Improvement of the post-harvest quality of strawberries
12. EU-FAIR CT96-1104: Novel high oxygen- and noble gas-modified atmosphere packaging (MAP) for extending the quality shelf-life of fresh-prepared produce (Novel MAP)
13. Novel packaging methods for domestic vegetables²
14. Nordfood project 93113: Fish, transport and packaging/Retail packaging of fish and fish products
15. Improvement of shelf-life and safety of fresh fish and fish products with minimal processing methods
16. EU-FAIR CT96-1020: Harmonization of safety criteria for minimally processed foods (Harmony)

Other projects

17. NI-network project: Minimal Processing - Preservation Methods of the Future
18. Management of Minimal Processing Research Programme

¹The project belonged to the Tekes Food Research Programme 'Uudistuva elintarvike'

²The project belonged to the Tekes Technology Programme of Packaging field

Table 2. The most important techniques studied in the VTT Minimal Processing Research Programme, their expected effects and foodstuffs to which these technologies were applied.

TECHNIQUES	EFFECT ¹	FOODSTUFFS	PROJECT NO (see Table 1)
High pressure technology	<ul style="list-style-type: none"> • Shelf-life (+) • Modification of texture (+ or -, depending on the raw material) • Promotion of marination (-) 	Fish products, meat, meat products, marinated meat, berries, vegetables	1, 2, 3
Supercritical extraction	<ul style="list-style-type: none"> • Promotion of marination (-) 	Marinated meat	2
Optimized sous-vide cooking (SVC)	<ul style="list-style-type: none"> • Shelf-life (+) • Safety (+) 	Meat-based ready-to-eat foods	4
Other novel processing techniques (light pulses, ultrasound, electric field pulses etc.)	<ul style="list-style-type: none"> • Shelf-life • Safety • Modification of texture 		5
SVC + nisin, and other compounds	<ul style="list-style-type: none"> • Safety (?) 	Meat-based ready-to-eat foods	4
Nisin	<ul style="list-style-type: none"> • Safety (+/?) • Shelf-life (+/?) 	Fish products, marinated meat	2, 4, 6, 12, 15
Nisin + high pressure technology	<ul style="list-style-type: none"> • Safety (+) • Shelf-life (+) 	Milk, marinated meat	2, 6
Nisin + various compounds (e.g., polyethyleneimine, lysozyme, thymol, organic acids)	<ul style="list-style-type: none"> • Safety (+) • Range of practical applications of nisin (+)² 	Milk, marinated meat, smoked fish	2, 6, 15
Novel antimicrobial compounds (e.g. lactobionic acid and mustard oil)	<ul style="list-style-type: none"> • Safety (?) • Shelf-life (+/?) 	Marinated meat	2
Dipping in various solutions containing effective compounds (over 50 different compounds and their combination were tested)	<ul style="list-style-type: none"> • Shelf-life (+) • Safety (+) • Inhibition of enzymatic browning (substitution of sulphite dipping) (+) • Texture after freezing (+) 	Fish products, pre-peeled potato and vegetables, strawberries	4, 8, 12, 15
Starch-based coating technology (edible coatings)	<ul style="list-style-type: none"> • Shelf-life (+) • Control of moisture migration (+) • Allocation of preservatives (precision effect) (+) 	Bakery products, cheese, fish products, pre-peeled potato	10, 12, 15
Antibacterial packaging materials	<ul style="list-style-type: none"> • Shelf-life (?) • Safety (?) 	Cheese, minced meat products	9
Novel packaging gases (N ₂ O, Ar, CO, high oxygen)	<ul style="list-style-type: none"> • Shelf-life (+, ?) • Safety (?) 	Fish products, marinated meat, strawberries, pre-peeled potato, vegetables	2, 11, 12, 13, 15
Novel selectively permeable packaging materials and packages	<ul style="list-style-type: none"> • Shelf-life (+) 	Strawberries and vegetables	11, 13

¹+ = confirmed positive effect, - = no effect, ? = no clear results, more research and development work is needed to verify the effects.

² Limitations of nisin revealed



Fig. 1. A laboratory- scale high pressure equipment suitable for kinetic studies as well as for product development.

2.3 Methodology

Various methods were used for evaluation of the function of preservation methods and quality and safety of processed and packed foodstuffs. The most important methods were:

- Experimental design and handling of results by statistical methods (e.g. Modde, software, Statgraphics software).
- Microbiological quality by conventional cultivation methods (aerobic bacteria, enterobacteria, sulphite-reducing clostridia, lactic acid bacteria, yeast and molds) and by rapid methods (automated turbidometry, impedometry).
- Microbiological risks by predictive microbiology using the commercially available computer-based programme Food MicroModel and Pathogen Modelling and by challenge testing with inoculated samples.
- Assays of the permeability alterations of the outer membrane of Gram-negative bacteria by hydrophobic probes, sensitization methods and membrane component release.

- Microscopic studies by using bright-field and confocal laser scanning microscopy (CLSM) and by Fourier transform infrared (FT-IR) microscopy.
- Sensory quality using analytical evaluation methods, such as multiple comparison, attribute intensity and quality scoring.
- Consumer research; the acceptability of low-sodium meat products among consumers was studied with home-use trials. Participants received low- and regular sodium product alternatives and tasted them at home. Liking for the products and buying intentions were rated and explained with sociodemographic variables and attitudes, such as general health interest and attitude towards the use of salt.

2.4 Other activities

The management committee of the Research Programme also drafted a new trademark, VTT Minimally Processed, and both basic and product-specific (process and packaging) specific criteria for the trademark. This trademark was designed to be an elite mark, the guarantee of a high quality product.

2.5 Dissemination of results

Every project and also the Programme itself had their own management committee composed of representatives of financing organisations, companies and research institutes. The results were reported to the management committees by VTT official research reports in the meetings. Scientific original papers as well as other professional papers, congress speeches and posters were also published. Seminar activity was an essential part of the programme. Seminars were organised both on the national and the international level. They have been listed in the following.

National seminars organised entirely or partly by the Minimal Processing Programme

1. Marjojen ja kasvisten teemapäivä VTT:llä. (R&D theme day of berries and vegetables at VTT). 2 October 1996, VTT, Espoo, Finland. 41 participants.
2. Keveät keinot elintarvikkeiden prosessointiin. Minimal processing-tutkimusohjelman vuosiseminaari (Mild methods for processing of foods. The annual seminar of the Research Programme on Minimal Processing). 26 November 1996, VTT, Espoo, 44 participants.

3. Minimal processing-tutkimusohjelman vuosiseminaari 'Keveät keinot elintarvikkeiden prosessointiin' (The annual seminar of the Research Programme on Minimal Processing). 19 November 1997, VTT, Espoo. 58 participants.
4. Kalavalmisteiden hygienia, prosessointi ja pakkaaminen -seminaari (Seminar on hygiene, processing and packaging of fish products). 9 April 1999. VTT, Espoo. 55 participants.
5. Seminaari 'Elintarviketeollisuuden uudet prosessointi- ja kypsennysmenetelmät' (the seminar 'Novel processing and cooking methods in the food industry'). 26 August 1998. VTT Biotechnology and Food Research. 20 participants.
6. Kasvisseminaari (Vegetable seminar) 2 September 1999, VTT, Espoo. 50 participants.

International Congresses and Seminars organised partly by the Minimal Processing Programme

1. International Symposium on Minimal processing and ready-made foods. 18–19 April 1996, SIK, Göteborg, Organisers: SIK and VTT. 75 participants.
2. The International Congress Agri-Food Quality II. Quality Management of Fruits and Vegetables - from Field to Table. 22–25 April 1998, Turku, Finland, Organisers: MTT, VTT and COST Action 915. 177 participants.
3. Seminar on Industrial biological preservation of foods - theory, applications and legal aspects. 10–11 June, 1998. Science Park, Aarhus, Denmark, Organisers: Nordic network on Minimal Processing and VTT. 45 participants.
4. Seminar on Post-harvest technologies for fruit and vegetables 10–11 September 1998, VTT, Espoo. Organisers: VTT and Nordic network on Minimal processing. 55 participants.
5. Fresh Novel Foods by High Pressure. International Symposium, 21–22 September 1998, Arctia Hotel Kalastajatorppa, Helsinki, Finland. Organisers: VTT and Katholieke Universiteit Leuven. 88 participants.
6. Seminar on Modified atmosphere packaging - An update. 12 March 1999, SIK, Gothenburg, Sweden. Organisers: Nordic network on Minimal Processing and VTT. 50 participants.

7. European Conference on Emerging Food Science and Technology, 22–24 November 1999. Hotel Rosendahl, Tampere, Finland. Organisers: EFFOST, VTT, Finnish Society of Food Science & Technology, European Commission DGXII and Nordic network on Minimal Processing. About 145 participants.
8. Other congresses and seminars in which the content or results of Minimal processing Programme and its projects have been presented are listed in the Appendices summarising the projects and their achievements.

The membership of scientific or organising committees of International Symposiums

1. Second European Symposium on Sous vide, 10–12 April 1996, Leuven, Belgium.
2. International Symposium on Food Packaging - Ensuring the Safety and Quality of Foods, 11–13 September 1996, Budapest, Hungary.
3. Third European Symposium on Sous-Vide, 25–26 March 1999, Leuven, Belgium.
4. Second International Symposium on Food Packaging - Ensuring the Safety and Quality of Foods, 8–10 November 2000, Vienna, Austria.

2.6 Cooperation

National and international cooperation was also an essential part of the Programme. All in all, 12 projects from 18 projects were cooperative (7 projects on the national level and 5 projects on the international level). The most important partners in co-operation were:

1. Meat Research Institute, Hämeenlinna, Finland
2. University of Helsinki, Department of Food Technology (Meat Technology), Helsinki, Finland
3. University of Helsinki, Department of Food and Environmental Hygiene, Helsinki, Finland
4. Agricultural Research Centre of Finland, Jokioinen, Finland
5. ATO-DLO, Wageningen, The Netherlands
6. Alma University Restaurants, Leuven, Belgium
7. Campden & Chorleywood Food Research Association, Chipping Campden, UK
8. Norconserv, Stavanger, Norway
9. SIK, Gothenburg, Sweden
10. Food and packaging companies, Finland and Scandinavia

3. RESOURCES AND FINANCING

The actual costs of the Programme at VTT Biotechnology were about 3.6 million EUR. Financing from VTT budget funds was about 1.4 million EUR (38.9%), financing from the National Technology Agency, EU - FAIR Programme and Nordisk Industrifond (NI) together was about 1.8 million EUR (50%) and from private companies about 0.4 million EUR (11.1%). The total working time for the Programme was 496.5 person months. All in all, about 60 research persons at VTT were involved in the Programme, part-time or whole-time. Furthermore, several persons attended sensory evaluations and the organisation of seminars and other dissemination of the results.

4. MAIN ACHIEVEMENTS OF THE PROGRAMME

The total number of research reports from the projects of the Programme is over one hundred. Some of them are non-public. In addition, three annual reports and one report on a trade mark were prepared from the Programme. A total of 26 original scientific papers including three Master's Thesis have been prepared from the results of the various projects of the Programme. Furthermore, 38 professional publications in international and national magazines have been published. Eighteen invited lectures and 19 scientific posters have been delivered. The amount of other publications (monographs, processing guides, lectures, chapters in books etc.) to date is 44. In addition, one patent application on the pre-treatment of strawberries for freezing and one training video on the treatment of fresh strawberries have been prepared (see Appendices 1–18).

4.1 Development of the minimal processing concept

The minimal processing concept, as such, was developed during the programme. It was clearly realized that the concept supports the idea of sustainable development. The criteria for minimally processed foods were created. These can be divided into basic criteria, which are not directly connected to any specific product, and product-specific criteria. All basic criteria should be valid, and on the other hand, of the product specific criteria at least criteria 1, 2, 3, 4 and 7 should also be valid (see the criteria below), before the product can be regarded as minimally processed.

Basic criteria:

1. Valid certificated quality system in the company producing minimally processed foods.
2. Valid certificated environment system in the company producing minimally processed foods.
3. Traceable main raw materials and process conditions.

Product-specific criteria:

1. Main raw materials should be produced according to Good Agricultural Practices (IP- or organic production, high hygiene level).

2. As good as possible preservation of nutritional and sensory quality without compromising microbiological safety in the process.
3. Reduction or complete abandonment of the use of preservatives, or their replacement by natural preservatives/compounds. Minimal processing must not increase the use of preservatives.
4. When using mild methods, the use of energy should not increase, but rather an energy saving should be attained in the process as well as in the whole food chain.
5. Reduction in the number of processing stages can also be regarded as minimization of a process (minimal treatment).
6. Saving of costs in the process as well as in the value chain (optimized value chain).
7. Optimized packaging according to the precision packaging concept (Lyijynen *et al.* 1998).
8. Exploitation of secondary flow (e.g. peeling waste) and method of utilization.

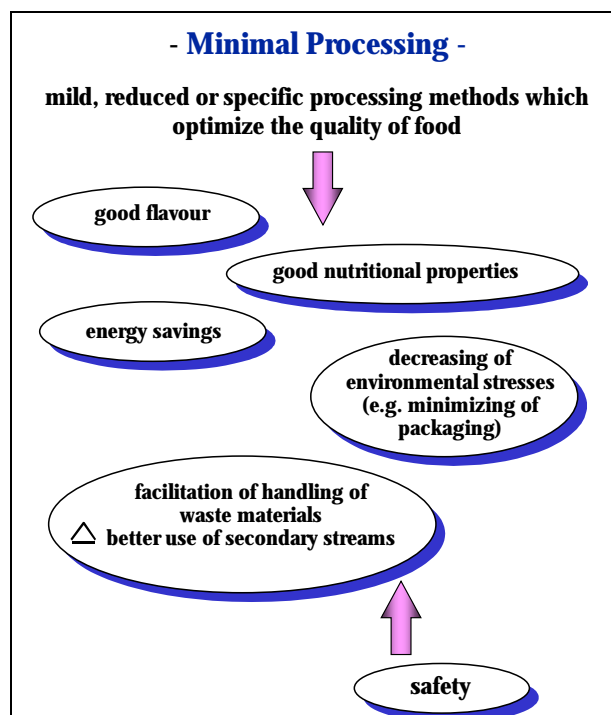


Fig. 2. The main aims of minimal processing without compromising the safety of foodstuffs.

At its best, minimal processing is an integrated approach beginning with raw material suitable for minimal processing, using processing methods without chemical preservatives and ending with packaging techniques increasing shelf-life (Figs. 2 and 3).

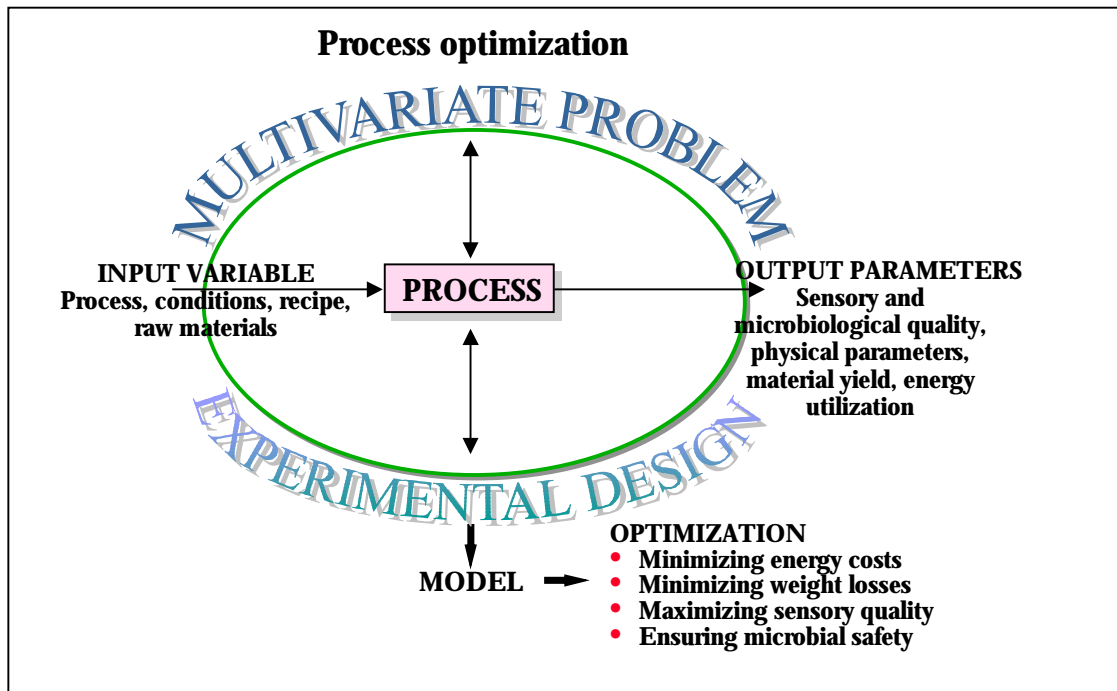


Fig. 3. Improved procedures for optimization of processes were developed in the Programme.

4.2 Trade mark VTT Minimally Processed

Preliminary questioning directed to food companies and other parts of the food chain indicated that the time was not yet ripe for this kind of trade mark. Certification of quality and environment systems should be more common than nowadays in order that even the basic criteria would exist for granting of the trade mark. However, the idea and content of the trade mark and the criteria for granting were regarded as relevant. Furthermore, the high number of various kinds of trade marks was criticized.

Because the minimal processing concept supports the imago of health-promoting properties of foodstuffs, the conclusion was that the combination of a message indicating both minimal processing and health-promoting properties of the food product into the same trade mark might be relevant in the future. However, the legislation concerning the marketing of health-promoting foods should first be developed. Furthermore, no trade mark available in the market nowadays contains a message from all aspects which consumers appreciate in the foods from the field to table; safety, health promotion, good sensory quality, environment, national. If new trade marks are to be prepared, these aspects should also be included in the mark (Appendix 18).

4.3 Some examples of the main results and their utilization

Safety

- Optimization and improvement of the safety of sous-vide cooking processes. Industrial processes were modified according to the results obtained in the Programme (Appendix 4).
- Lowering of the risk caused by *Clostridium botulinum* in sous-vide products was best achieved by modification of process conditions (cooking temperature and time) and in smoked fish products by the use of an edible coating containing sodium chloride and combined with modified atmosphere packaging (Appendices 4 and 15).
- Nisin, various organic acids and lactobionic acid were the most promising preservatives for meat and fish products. However, these compounds can be used only as an additional hurdle (Appendices 2 and 15).
- Improved procedures for optimization of processes and packages were developed in the Programme. Experimental design (e.g. surface response methodology) is an essential tool for optimization. In the Programme, this working approach was launched particularly for the meat and sous-vide industry (Fig. 4). Furthermore, process and recipe improvement is always a multi-stage procedure, in which e.g. computer-based programmes on predictive microbiology can help to reduce the number of experiments and to determine the optimum range of processing temperature and time or recipe conditions. It should be noticed in this connections that experimental design or predictive microbiology have hitherto been used very little in Finland in the product development of the food industry (Appendices 2, 3, 4, 8, 11, 12 and 13).
- Commercial computer-based programmes on predictive microbiology provide a useful tool for the preliminary risk assessment and product/process development. Nevertheless, in the final microbiological safety evaluation the use of inoculation assays is recommended, particularly when novel physical methods, such as high pressure technology, are to be used. (Appendices 1, 4, 5 and 16).
- The Programme also took part in the EU FAIR Concerted Action CT96-1020 project 'Harmonization of safety criteria for minimally processed foods'. Recommendations and possible methodologies for standardisation of safety criteria were given in the project (Appendix 16).

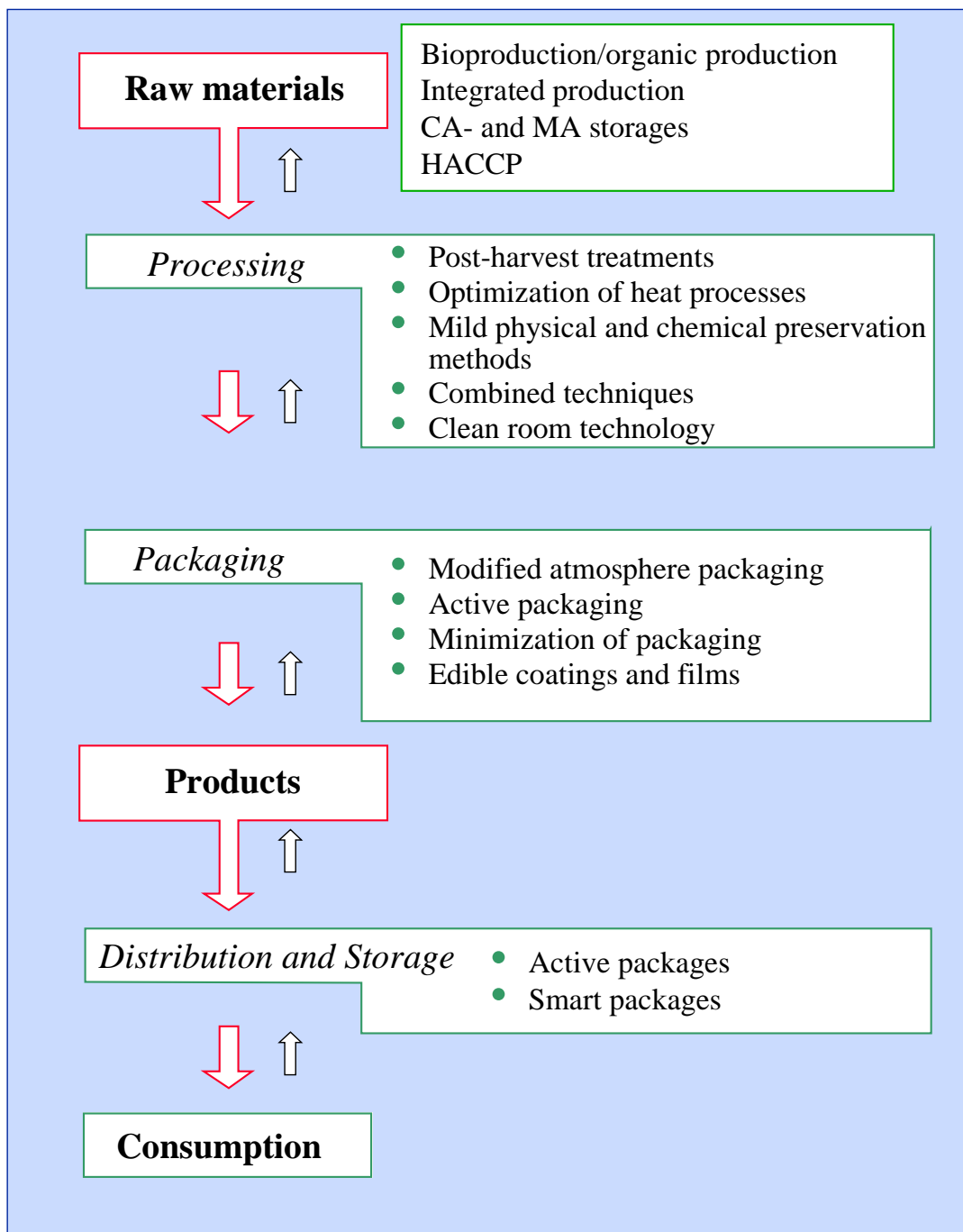


Fig. 4. An integrated approach is essential for the quality and safety of minimally processed food products.

Sensory quality

- In order to maintain the quality of fresh strawberries from the field to the table, an integrated approach is of paramount importance. Fresh strawberries sold in retail shops with the Star+ trademark in the summers of 1998 and 1999 had been treated according to the instructions formulated in the Programme (Appendix 11).

- Two different kinds of forced air-cooling systems practicable at strawberry farms were constructed, tested and taken into the use at many farms.
- Improvement of the texture of strawberry-based jams is possible by prefreezing treatment of strawberries in a vacuum in solutions containing calcium chloride and pectin methylesterase (PME). The developed method has been protected by a patent application (Appendices 7 and 8).



Fig. 5. Substitution of sulphites is possible in peeling processes of potatoes by combination of dipping in a solution containing organic acids and modified atmosphere packaging.

Nutritional properties

- The lowering of sodium content in meat products is possible by modification of recipes and in fish products by edible coating (Appendices 3 and 15). Consumers are prepared to accept meat products with reduced sodium content, and consumers also showed an interest, not only eating low-sodium meat products when served, but also in buying them. In the project meetings, the meat companies participating in the project 'Development of manufacturing techniques for meat products with low sodium content' (Appendix 3) have expressed their satisfaction with the results. The consumer attitudes towards fish products with reduced sodium content were not studied. However, it is clear that low-sodium alternatives provide consumers with the option of lower sodium intake.

- Substitution of sulphites is possible in peeling processes of potatoes by combination of dipping in a solution containing organic acids and modified atmosphere packaging (Appendix 12) (Fig. 5). The nutritional properties as well as the sensory quality of pre-peeled potatoes is better after treatment with this new combination method than after sulphite treatment.

Novel processing and packaging technologies

- High pressure technology, ultrasound, light pulses and electric pulses were found to be the most promising novel physical methods for preservation and modification of foods. However, practical experimental work was carried out only with high pressure technology.
- High pressure technology increases the shelf-life of various foods, such as cooked meat products, fish products, berry and vegetable products. The best result will be obtained by combination with other techniques, e.g. temperature and chemical and biological preservatives (nisin, lysozyme), thus decreasing the necessary pressure level and making the process cheaper. The interest of many food companies in high pressure technology increased significantly during the Programme, even though it is a rather expensive technology. High pressure technology will have potential in some special, gourmet food products to ensure a long shelf-life. However, before the technology is ready for industrial use, much practical experimental work will still be needed e.g. to verify the microbiological safety of pressurized products and to optimize the process (Appendices 1, 2, 3, 5, 6). The present legislation on novel foods will also delay the adoption of high pressure technology to some extent, because it demands an application for authorisation of the food product produced by high pressure technology.
- No physical method studied was successful in making raw meat more tender (Appendix 2).
- Much new information about the possibilities of novel modified atmosphere packaging using hydrogen, argon, nitrous oxide, carbon monoxide and high oxygen for packaging of fish products, marinated meat, vegetables and strawberries was obtained. Of the novel gases, carbon monoxide and argon were the most promising (Appendices 2, 11, 12, 13, 14, 15). On the other hand, for vegetables and strawberries, suitably permeable packaging film is more important than the gas mixture (Appendices 11 and 13).
- Minimization of packaging of bakery products is possible with edible coatings. Edible coating and incorporation of various preservatives and other compounds with coating is a very promising technique to improve the quality and the shelf-life of various food products (Appendices 10, 12 and 15) (Fig. 6).



Fig. 6. Starch-based edible coatings can improve the shelf-life of various foods such as bakery products, fish and vegetables.

4.4 The benefit for food and packaging industry

The most significant benefit for the the industry has been the generation of practical information about current processing topics. Strategically important in the Programme was that novel methods were studied for real and relevant foodstuffs and food raw materials, and that in quality and shelf-life studies both microbiological and sensory quality (appearance, flavour, texture) were considered. Most of the available information in the scientific literature deals with the effects of novel methods in laboratory media, or the effects have been studied to a limited extent, ignoring e.g. the sensory evaluation of flavour of treated food. Thus the results presented in the literature are often too promising; a compound or a method which works in laboratory conditions does not necessarily work in a real food. This was found, for example with nisin, some potential browning inhibitors and some novel packaging gases.

Much information was obtained about the possibilities of various novel processes, preservation methods and packaging technologies to minimize the harmful effects of processes on sensory and nutritional quality without microbiological safety risks. Optimized traditional processes and recipes, combined methods and integrated approaches were found to be the most promising ways to maintain the quality and ensure the safety of foodstuffs. The significance of quality management from the field to the table or from raw material production to the consumer was emphasized by the results of the Programme. The minimal processing concept has been well adopted in industry (see e.g. FINPRO's publication, Appendix 18). Industry has obtained tools for their product development and decision making. The benefit for the food industry is the ability to produce and market internationally competitive products that are in compliance with regulations.

4.5 Other results

The Gold Key 2000 award of the Association for Finnish Work to the manager of the Programme, Dr. Raija Ahvenainen, was an indication of the high regard of the minimal processing concept by society. The grounds for granting of the award given by the jury were the following: Raija Ahvenainen is a pioneering, internationally recognised Finnish developer of the pure food production chain. The ground for the competitiveness of the food sector in Finland is pure foodstuffs, pure food products and good management of the food production chain. With her research group Raija Ahvenainen performs valuable, innovative work by solving and developing novel food processing and packaging concepts in which product safety, improved quality, convenience and energy savings are emphasized. The jury was led by Minister Kimmo Sasi.

The Programme increased significantly generic basic know-how on minimal processing and its possibilities in developing safe, tasty and nutritional foodstuffs. This know-how can be utilized in research and development projects carried out with the food and packaging industries. Hitherto, at least nine (9) product development projects not included in the Programme have been started with food companies on the basis of the results of the programme, mainly on high pressure technology and edible coating. Furthermore, at least four (4) EU projects have been approved on high pressure and packaging topics. Furthermore, several national and international projects are under preparation (Appendices 1–18).

5. FUTURE PROSPECTS

Healthy, convenient and environmentally friendly foodstuffs are becoming more important for consumers. Safety is a self-evident criterion. As competition and product assortment increase, high sensory quality will become an increasingly important competitive advantage. The minimal processing concept supports all these demands set by consumers.

Much research and development work must still be carried out in order to develop minimally processed food products which satisfy consumers and which have high sensory quality, microbiological safety and nutritional value.

Quality

The characteristic feature in minimal processing is an integrated approach, in which raw materials, handling, processing, packaging and distribution must all be properly considered to make shelf-life extension possible. In the Programme, the integrated approach from the field to the table was found to be the most promising way to maintain high quality and ensure the safety of fresh foodstuffs, such as strawberries and fish. In the integrated approach considerable emphasis is placed on the treatment of food during and immediately after harvesting. The correct degree of ripeness, gentle treatment in harvesting, careful and rapid chilling, low temperature in storage and during distribution and as little mechanical stress as possible after harvesting are key points to ensure the quality and shelf-life. With strawberries, reduction of mechanical stress means that they should be picked directly into the consumer package. This kind of approach can also be applied to other cultivated berries for example to bush blueberry, the cultivation of which is increasing in Finland.

According to discussions with vegetable packers, nowadays the chilling of vegetables after harvesting at farms is not effective enough. Forced air-cooling systems developed in the Programme for strawberries might also be applicable for vegetables. The advantages of the systems are that they are very cheap and can be constructed inside the refrigeration rooms of farms.

The unit operations, such as peelers and shredders for vegetables and potatoes, need further development to make them more gentle. There is no sense in disturbing the quality of produce by rough treatment during processing, only to patch it up later by preservatives. One possible solution is a combination of enzymes (cellulases, hemicellulases and pectinases) with mechanical peeling (carborundum or knife peeling).

As already mentioned, the most promising novel technologies studied in the Programme were high pressure technology and coating technology. The number of the research and development projects started based on the results of the Programme confirms this. Ultrasound, electric pulses and light pulses are also promising technologies, the point of view of both shelf-life and product modification. However, the problem is that particularly light pulses are still very expensive and in their infancy. One reason for their high cost may be that there is only one manufacturer for this technology in the world. It should be carefully considered whether there are possibilities to construct a method based on light pulses on the national level. In any case, profitable, inexpensive physical methods for lowering microbial counts as well as for modification of food structure and formulation of new flavour properties are needed in the future for the production of fresh foods (also raw foods) and novel food products of high quality.

Consumer attitudes towards food products manufactured by novel methods should be studied. For example, in the Programme it was shown that high pressure technology is a promising way to increase the shelf-life of raw meat, fish and vegetables, but it changes the sensory quality so much that consumers may not accept them. However, for sterile foods, high pressure technology combined with chilling technology is a way to produce high quality products with low microbiological risks compared to traditional foods. Particularly, vegetables and hard roe are potential raw food products to be treated by high pressure.

Safety

In this Programme, minimal processing methods were mainly applied for reduction of the harmful effects of severe cooking processes and preservatives (such as sulphites, sodium chloride), or to increase the shelf-life of short-shelf food products (e.g. marinated meat, raw and smoked fish, vegetables), without compromising microbiological safety or sensory quality. Naturally, in the future shelf-life and safety improvement as well as reduction of preservatives or other harmful compounds will be of interest, e.g. in the substitution of nitrites, phosphates or glutamates in meat products. Thus, the search for potential natural compounds and the study of their combination with physical methods should still continue. Ozone, chitosan and mustard oil are among the promising compounds, but there are also many others, e.g. essential oils. The combined methods should be studied with real foodstuffs.

The antimicrobial packaging materials are also one potential way to decrease the amount of preservatives and focus the function of preservatives more precisely where microbial growth and spoilage mainly occur, on the surface of the food. However, these materials are still rather rare on the market and need much research and development

work. Research on packaging and food preservation at VTT should focus on the development of these materials in the future.

As already mentioned, coating technology also appeared to have promising possibilities as a 'precision weapon' in many applications, e.g. on the surface of smoked fish products, but needs still further development. Coating technology combined with high local sodium chloride content was a promising method to hinder the growth of *Clostridium botulinum*. A similar approach should be studied against Listeria, which is together with *Clostridium botulinum* one of the most typical pathogenic bacteria in fish products. VTT Biotechnology has know-how mainly on starch-based coating technology. The problem with starch-based coatings found in the Programme was mould growth in some cases, probably caused by contamination of the coating. Thus, preparation of the coating needs further development. VTT starch-based coatings should also be compared with commercially available carbohydrate-based coatings, e.g. in the project 'Management of the quality and safety of minimally processed vegetables by novel methods', started in March 2000.

In general, future research should be primarily focused on the microbial ecology of minimally processed foods and the growth characteristics and interactions of pathogenic and spoilage organisms during and after combined treatments. The microbe-food interactions are always product-related, as are the microbial metabolites produced during spoilage and prolonged shelf-life. Future innovations for food product safety are therefore dependent on the basic research on microbial ecology and metabolism in foods.

Healthiness

During the Programme health-promoting foods attracted considerable interest for product development in the food industry. VTT Biotechnology started a 4-year Research Programme on Future Foods in 1997. One of the aims of this programme is to improve health-promoting effects of foods, e.g. with bioactive compounds of vegetables. In some projects of the Future Foods Programme, process effects on bioactive compounds have also been studied and the optimization of processes has been started. The minimal processing concept supports the trend to produce health-promoting foods by preserving nutritional compounds in foods. In the literature, there are also indications that certain minimal processing methods can be used for reduction of allergenic compounds in food products. Therefore, when developing health-promoting foods emphasis should also be placed on the preservation of beneficial compounds already existing in the food raw material as well as on the removal of harmful compounds. Often, from the legislative point of view, this might even be even an easier

way to develop health-promoting foodstuffs than the approach in which health-promoting compounds are added to the food product.

Legislation

One problem arising during the Programme was the current food legislation. For example, malic acid combined with ascorbic acid and modified atmosphere packaging was found to be a promising method to substitute sulphites in the browning inhibition of pre-peeled potatoes. Another example is the use of carbon monoxide gas in packaging, which already at very low concentrations (0.1–0.3 %) allows the packaging of retail red meat without high oxygen levels, retaining the natural colour of meat as valued by consumers. Current legislation does not allow the use of malic acid for pre-peeled potatoes or carbon monoxide for packaging. However, it is worth noticing that potato itself contains malic acid, which is also a typical compound in apples. Carbon monoxide has been used for meat packing in Norway for several years. Change of legislation or the granting of a special permit for use from the authorities is very slow in the EU. The attendance of representatives of the authorities in research and development projects aiming at novel methodologies for food preservation will be essential to accelerate the approval of novel methods in the future.

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**VTT Research Programme on Minimal Processing of Foods
Summary of the project**

The title of the project FOOD APPLICATIONS OF HIGH PRESSURE TECHNOLOGY		Project leader Olavi Myllymäki	
Timetable (Planned duration and person months) 1.1.1994–31.12.1996, 15 pm		Timetable (Actual duration and person months) 1.1.1994–31.7.1996, 18 pm	
Project group <u>Scientists:</u> Raija Ahvenainen, Chief Research Scientist Riitta Kervinen, Research Scientist Kati Randell, Research Scientist Olavi Myllymäki, Research Scientist Eija Skyttä, Research Scientist <u>Technicians:</u> Anne Ala-Kahrakuusi, Heidi Eriksson, Ulla Österlund		Chairman of the management committee Research Professor Kaisa Poutanen, VTT	
Budget x 1000 FIM 735		Actual costs x 1000 FIM 835	
Financing from VTT x 1000 FIM (%) 485 (58%)	Tekes/MMM x 1000 FIM (%) 350 (42%)	EU x 1000 FIM (%)	Companies x 1000 FIM (%)
Industrial partners LSO-Foods Oy Saarioisten Säilyke Oy Chymos Oy		Partners from research institutes SIK, Gothenburg, Sweden	
Objectives of the project The objectives of this applied research were to study the applicability and feasibility of high pressure technology in the Finnish food industry. The emphasis was on products considered vital by the participating companies: fresh and prepared meat products, fish, frozen food, vegetables and berries.			
Main achievements of the project <ul style="list-style-type: none"> • High pressure treatment at 500–700MPa at 0–20 °C for 5–15 min was an effective mean to increase the microbial shelf-life of packed foods. • The most potential and successful applications of high pressure processing were for prepared meat such as sausages, meat in aspic, ham etc. In these products the total counts of bacteria were effectively decreased at 500–700 MPa at +4 °C in 10 minutes and ensured the shelf-life of processed food over a period of several months during cold storage. During processing the taste, color and texture remained unchanged. • The rapid tenderization of meat (loin) was achieved only at elevated temperatures (at 70 °C) at 250–400MPa in 20–30 minutes. However, these process conditions produced cooked-like meat. • High pressure processing increased the shelf-life of hot smoked fish. • High pressure processing of vegetables was a promising unit operation as part of the minimal processing concept. • High pressure processing is suitable in manufacturing stable jam products with high berry content in which the berries remain intact. 			
Profit made from the achievements Much basic knowledge about the suitability and possibilities of high pressure processing for various kinds of food products was obtained.			

VTT Research Programme on Minimal Processing of Foods Summary of the project

Further research needs and prospects. New projects started based on this reported project.

Further research needs are:

- The utilization of hydrophobic interaction in combining aromas or other hydrophobic components with food.
- The restructurization and recombination of food (meat and fish products).
- Microbial inactivation of food components at low temperatures.
- Combination of high pressure with other preservation methods.

Several projects have been started:

- High pressure was applied in the other projects of the Research Programme (e.g. Development of meat marination and Development of manufacturing techniques for meat products with low sodium content) and combined with other techniques (see the Summaries of the projects, Appendices 2 and 3).
- The know-how, experience and contacts in this project led to participation in a 3-year EU-FAIR-CT96-1175 project 'Combined high pressure thermal treatment of foods: A kinetic approach to safety and quality evaluation' (1996–1999), in which VTT as a partner purchased its own small high pressure processor.
- In September 1999, a 2-year R&D project 'Manufacturing of special food products by high pressure technology' was started. The project is financed by Tekes, companies and VTT.
- Two confidential projects, with VTT as a partner, in which high pressure processing will be studied to lengthen the self-life of some food products and to produce new types of products. This may lead to establishment of high pressure processing as a unit operation in the food industry in the near future.

Publications (also manuscripts)

Scientific publications

1. Myllymäki, O., Kervinen, R., Skyttä, E., Hattula, T. & Ahvenainen, R. 1997. High pressure processing of fish and fish products. In: Heremans, K. (Ed.) High Pressure Research in the Biosciences and Biotechnology, Leuven University Press, Leuven, Belgium, p. 447–450.

Professional publications

1. Myllymäki, O. & Kervinen, R. 1995. Suurpainetekniikka-tutkimusta ja sovelluksia. Kehittyvä elintarvike 6, No 2, 28–32

Other dissemination (congresses, seminars, training courses)

Posters

1. Kervinen, R., Myllymäki, O. & Ahvenainen, R. Improvements of the stability of minimally processed carrot by high pressure technology. 9th World Congress of Food Science and Technology, July 30 - August 4, 1995, Budapest. Abstr. Vol. II, 77. Abstract P218.
2. Kervinen, R., Myllymäki, O., Autio, K., Forssell, P. & Poutanen, K. Effects of high pressure treatment on potato and barley starch suspensions. 9th World Congress of Food Science and Technology, July 30 - August 4, 1995, Budapest. Abstr. Vol. II, 77.
3. Myllymäki, O., Kervinen, R., Skyttä, E., Hattula, T. & Ahvenainen, R. High pressure processing of fish and fish products. European High Pressure Research Group, XXXIVth Meeting High Pressure Bio-Science and Bio-Technology, Katholieke Universiteit Leuven, Belgium, 1–5 September 1996. Poster Abstract P70.

VTT Research Programme on Minimal Processing of Foods Summary of the project

Others

1. Myllymäki, O. Suurpainetekniikka elintarvikkeiden käsittelyssä - käytännön esimerkkejä (High pressure technology in processing of foods - practical examples). Keveät keinot elintarvikkeiden prosessointiin. Minimal processing-tutkimusohjelman vuosiseminaari (Mild methods for processing of foods. The annual seminar of the Research Programme on Minimal Processing), VTT, Espoo, 26 November 1996, oral presentation.
- Seminar for Finnish food industry " High pressure technology in food industry" at VTT 5 October 1995.

VTT Research Programme on Minimal Processing of Foods

Summary of the project

The title of the project DEVELOPMENT OF MEAT MARINATION		Project leader Kaisu Honkapää (at VTT)	
Timetable (Planned duration and person months) 1.4.1997–31.3.2000, 43 pm		Timetable (Actual duration and person months) 1.4.1997–31.3.2000, 44 pm	
Project group <u>Scientists:</u> Raija Ahvenainen, Chief Research Scientist Kaisu Honkapää Research Scientist Ilkka Helander, Senior Research Scientist Tiina Luoma, Research Scientist Pirkko Nousiainen, Research Assistant Olavi Myllymäki, Research Scientist Eija Skyttä, Research Scientist Martina Stolt, Research Scientist <u>Technicians:</u> Anne Ala-Kahrakuusi, Heidi Eriksson, Heli Nykänen, Aila Tuomolin, Ulla Österlund		Chairman of the management committee Heljä Mantere, Liha-Saarioinen Oy (1.4.1997–29.1.1999) Mikko Pajari, HK Ruokatalo Oyj (29.10.1999–)	
Budget x 1000 FIM 1 835 (VTT's part of the project)		Actual costs x 1000 FIM 1778 Extra financing was obtained for the period 1.4.–31.12.2000.	
Financing from VTT x 1000 FIM (%) 364 (20.5%)	Tekes x 1000 FIM (%) 1083 (60.9%)	EU x 1000 FIM (%)	Companies x 1000 FIM (%) 331 (18.6%)
Industrial partners Atria Oyj, HK Ruokatalo Oyj, Karjaportti, Liha-Saarioinen Oy, LTK-Maustepalvelu Oy, Oy Aga Ab, Oy Snellman Ab, Pimenta Oy (1.4.1997–31.3.1999), Valio Oy		Partners from research institutes Finnish Meat Research Institute FMRI (LTK) (coordinator), University of Helsinki / Department of Food Technology	
Objectives of the project The aim of the project was to improve the tenderness, safety, shelf-life, sensory properties and healthiness of ready-marinated meat products as well as to develop new processing methods. VTT has worked with modified atmosphere packaging, high pressure technology, supercritical CO ₂ extraction and natural antimicrobial agents, e.g. nisin and novel antimicrobials. VTT has also provided sensory evaluation services to the other research institutes.			
Main achievements of the project <ul style="list-style-type: none"> • Supercritical carbon dioxide extraction did not make meat tender, neither was it a practical way of seasoning meat. Therefore, it is not a useful processing method for marinated meat. • It was found that it is possible to tenderize meat with high pressure, but that processing temperature was a very important factor in the success of the tenderization. High pressure tenderization seems not to be suitable for fresh meat products. For fresh meats only low pressures (1000–2000 bar) can be used in order to avoid discoloration. This complicates the use of high pressure in increasing the shelf-life of fresh meat products. • Storage temperature is an extremely important factor affecting the shelf-life of marinated meat products. • High concentration of carbon dioxide with nitrogen and high oxygen concentration with carbon dioxide are traditional gas mixtures used in modified atmosphere packaging of meat. High CO₂ inhibits the growth of many microorganisms, but the colour of meat becomes brown in CO₂-N₂-mixtures. High O₂ concentrations impart a bright red colour to meat, but the colour is unstable and 			

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Summary of the project

microbes are not inhibited effectively. Oxygen can also induce off-odours to packaged meat. Traditional gas mixtures are therefore not ideal for fresh meat. According to our results a small amount of carbon monoxide in a CO₂-N₂-mixture gives packaged meat a stable bright red colour without the negative effects of traditional high oxygen or high carbon dioxide concentrations. The results of a consumer acceptability trial of marinated meat packaged in either high oxygen without carbon monoxide or high carbon dioxide with carbon monoxide inclusion showed that consumers judged meat colour in packages containing carbon monoxide to be nearly as typical as the colour in high oxygen packages. Other novel packaging gases tested in this project (argon, hydrogen and nitrous oxide) or the use of oxygen absorbers appeared not to be promising in the packaging of marinated meat products.

- The use of nisin was investigated to increase the shelf-life and safety of marinated meat products. Nisin was used in the marinade alone and in combinations with different antimicrobial compounds, for example with thymol. Modified atmosphere packaging was always used with nisin. The combined effect of nisin and high pressure processing was also investigated. Nisin slowed down the growth of particularly Gram-positive spoilage bacteria. A major part of the nisin work in the marination project was performed in cooperation with the EU-project NisinPlus (see Appendix 6).
- Novel natural antimicrobial agents, for example lactobionic acid, mustard oil and chitosan, are currently under investigation.

Profit made from the achievements

- The research knowledge of marinated meat products has improved significantly.
- The experience of using a small amount of CO in meat packages has increased remarkably in the Finnish meat industry. The industrial partners have been very interested in using CO in packages, provided that the legislation changes to make it possible.
- The industrial partners have obtained much information about the shelf-life and safety of marinated meat products and knowledge about new possibilities of increasing product shelf-life and safety.
- The companies involved have had new ideas and possibilities for producing new kinds of marinated meat products.

Further research needs and prospects. New projects started based on this reported project.

An application was made for continuation of this project over the period 1.4.–31.12.2000 because many interesting aspects still need additional research. For example, safety of marinated meat products, different marination techniques and combining the most promising new methods to produce and package marinated meats will be investigated in the project continuation. Tekes and companies allocated funding for this continuation.

Publications (also manuscripts)

- The project continues and the results are still confidential to the project participants, and therefore no publications have been prepared hitherto.
- Forty-three (43) confidential research reports concerning the research results have been prepared and distributed to the industrial participants. Seventeen (17) of these reports were prepared by VTT research scientists.

Other dissemination (congresses, seminars, training courses)

In addition to management committee meetings, the results obtained in the project have been presented to the R&D and marketing personnel of the participating companies in private meetings.

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Summary of the project

The title of the project DEVELOPMENT OF MANUFACTURING TECHNIQUES FOR MEAT PRODUCTS WITH LOW SODIUM CONTENT		Project leader Raija Ahvenainen (at VTT)	
Timetable (Planned duration and person months) 1.4.1997–31.3.2000, 36 pm		Timetable (Actual duration and person months) 1.4.1997–31.3.2000, 41 pm	
Project group <u>Scientists:</u> Raija Ahvenainen, Chief Research Scientist Anne Arvola, Research Scientist Kaisu Honkapää, Research Scientist Liisa Lähteenmäki, Senior Research Scientist Olavi Myllymäki, Research Scientist Eija Skyttä, Research Scientist Martina Stolt, Research Scientist Nina Urala, Research Scientist Jukka Vainionpää, Senior Research Scientist <u>Technicians:</u> Anne Ala-Kahrakuusi, Pirkko Nousiainen, Eeva-Kaisa Peltokorpi, Aila Tuomolin, Ulla Österlund		Chairman of the management committee Prof. Eero Puolanne, University of Helsinki / Department of Food Technology	
Budget x 1000 FIM 1 650 (VTT's part of the project)		Actual costs x 1000 FIM 1551 Extra financing has obtained for 1.4.–31.12.2000.	
Financing from VTT x 1000 FIM (%)	Teikes x 1000 FIM (%)	EU x 1000 FIM (%)	Companies x 1000 FIM (%)
85 (5.5%)	840 (54%)		560 (36%)
Industrial partners Atria Oyj, HK Ruokatalo Oyj, Karjaportti, Lihansavustamo Pekka Pajuniemi Oy, Liha-Saarioinen Oy, LTK-Maustepalvelu Oy, Oriola Oy Reformi-keskus, Oy Snellman Ab, Pouttu Oy, Tapola Oy, Valio Oy, Yrjö Wigren Oy		Partners from research institutes University of Helsinki / Department of Food Technology (coordinator), Finnish Meat Research Institute FMRI (LTK)	
Objectives of the project The aim of this research project was to develop new processing methods and recipes for low-sodium meat and minced meat products. VTT worked with statistical experimental designs and analysis of results in the recipe development part of the project, high pressure technology, shelf-life testing and consumer acceptability trials. VTT also provided sensory evaluation services to the other research institutes.			
Main achievements of the project <ul style="list-style-type: none"> • The use of statistical experimental designs was a new kind of approach to the development of meat products. Statistical experimental designs and analysis of results proved to be an effective way of developing recipes for meat products with lowered sodium content, because many different binding and extending agents and their mixtures could be dealt with in the same test series. Recipes were adjusted so that both the texture and the sensory properties of meat products were satisfactory. • High pressure appeared to improve the texture of heated cooked sausages with low sodium content. The vessels of VTT's high pressure processing equipment are very small, which made it difficult to perform experiments on the sensory analysis of processed meat products. 			

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Summary of the project

- The shelf-life of meat products with lowered sodium content was found to be rather complex. In some experiments problems were encountered in the shelf-life of sausages, although it was not clear how much the reduced sodium content affected the shelf-life.
- The consumer acceptability trials were made with ring sausages, sliced bologna-type sausages, whole-meat products and minced meat products. The results of these trials were very promising, because they showed that most consumers were ready to accept meat products with reduced sodium content. The consumers showed an interest not only in eating these low-sodium meat products when served but also in buying them.

Profit made from the achievements

- The companies involved have obtained new ideas about producing low-sodium meat products. The companies have already started to apply the results of this project in their industrial processes.
- Statistical experimental methods were useful in recipe development. This may encourage the industrial partners to use such methods in their product development processes.
- The industrial partners obtained proof of consumer interest in buying low-sodium meat products, which encourages them to bring this kind of products to the market.
- Lower sodium content in meat products may have a positive effect on public health in Finland.

Further research needs and prospects. New projects started based on this reported project.

An application was made for continuation of this project over the period 1.4.–31.12.2000 because many interesting aspects still need additional research. For example, shelf-life and safety of low-sodium meat products and adaptation to low-sodium diet are to be investigated in the project continuation. Tekes and companies allocated funding for this continuation.

Publications (also manuscripts)

- The project continues and the results are still confidential to the project participants, and therefore no publications have been prepared hitherto.
- Two confidential annual reports and several experiment reports have been distributed to the participants.

Other dissemination (congresses, seminars, training courses)

Two annual seminars to the participating companies have been held, in which the results of the project were presented. VTT presented the results of high pressure and shelf-life experiments and consumer acceptability trials.

VTT Research Programme on Minimal Processing of Foods Summary of the project

The title of the project OPTIMIZATION AND SAFETY IMPROVEMENT OF SOUS VIDE COOKING		Project leader Eija Skyttä	
Timetable (Planned duration and person months) 2.2.1997–31.12. 1998, 27 pm		Timetable (Actual duration and person months) 2.2.1997–31.5. 1999, 27 pm	
Project group <u>Scientists:</u> Raija Ahvenainen, Chief Research Scientist Arvo Kinnunen, Research Scientist Liisa Lähteenmäki, Senior Research Scientist Mirja Mokka, Senior Research Scientist Eija Skyttä, Research Scientist <u>Technician</u> Anne Ala-Kahrakuusi, Pirkko Nousiainen, Aila Tuomolin, Ulla Österlund		Chairman of the management committee Asko Mäyry, Atria Oyj	
Budget x 1000 FIM 1 320		Actual costs x 1000 FIM 1 323	
Financing from VTT x 1000 FIM (%) 144	Tekes/MMM x 1000 FIM (%) 936	EU x 1000 FIM (%)	Companies x 1000 FIM (%) 240
Industrial partners Atria Oyj HK Ruokatalo Oyj Liha-Saarioinen Oyj Helsinki Catering Oy Sodexo Oy (formerly Polarkesti Oyj)		Partners from research institutes Helsinki University, Faculty of Veterinary Medicine, Department of Food and Environmental Hygiene	
Objectives of the project The key objective of the project was to optimise a range of sous vide processes used by the food industry in Finland. Emphasis was focused on the microbiological safety and sensory quality of sous vide products prepared from domestic raw materials. For prediction of product safety two commercially available predictive microbiology programs were applied. The programs were preliminarily evaluated for applicability as tools in prediction of product safety of ready-to-eat foods. The risk due to <i>Clostridium botulinum</i> risk was examined by inoculation assays. For improving the microbiological safety both recipe variables and other additional hurdles were studied. In parallel, optimal heat treatment conditions were calculated and thereafter assessed by inoculation assays.			
Main achievements of the project <ul style="list-style-type: none"> • The preliminary risk assessment revealed that most of the original processes studied were insufficient from the point of view of microbiological safety. • Although the processes were considered too mild, no failures in microbiological or sensory quality were demonstrated. • In several products, the risk of growth and toxin production by <i>C. botulinum</i> was evident under temperature abuse conditions. • Recipe components such as sodium chloride (NaCl) and acetic, citric and lactic acids could not be used in high enough concentrations to improve the microbiological safety because they caused negative changes in the sensory quality. • Nisin at a concentration level of 500 IU/g did not inhibit the outgrowth of <i>C. botulinum</i>. • A six decimal reduction of <i>C. botulinum</i> was only achieved by an intensified heat treatment tailored to each product by a predictive model. • Intensified heat treatment affected the sensory quality to some extent. The changes in sensory quality were regarded as positive or negative depending on the type of product. 			

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Summary of the project

- Conclusion: The safety of all sous vide products must be carefully evaluated.

Profit made from the achievements

- The food industry producing sous vide products is currently well aware of the risks related to sous vide processing.
- The results obtained could be adopted in practice without delay.
- Predictive models provide a useful tool for the preliminary risk assessment and product/process development. Nevertheless, in the final safety evaluation of new sous vide products, inoculation assays are recommended to be used.
- The cooperation network between research institutions and industry was fruitful and provides useful links for new projects with a multidisciplinary approach.

Further research needs and prospects. New projects started based on this reported project.

- The demand for optimisation of heat treatment processes continues in the food industry.

Publications (also manuscripts)

Together 20 research reports were written for industrial partners.

Scientific publications

1. Hyttiä, E., Skyttä, E., Morkkila, M., Kinnunen, A., Lindström, M., Lähteenmäki, L., Ahvenainen, R. & Korkeala, H. 2000. Safety evaluation of sous-vide processed products with respect to non-proteolytic *Clostridium botulinum* using challenge studies and predictive microbiological models. Applied and Environmental Microbiology 66, No 1, 213–218.
2. Hyttiä, E., Hielm, S., Morkkila, M., Kinnunen, A. & Korkeala, H. 1999. Predicted and observed growth and toxigenesis by *Clostridium botulinum* type E in vacuum-packaged fishery product challenge tests. International Journal of Microbiology 47, pp. 161–169.
3. Lindström, M., Morkkila, M., Skyttä, E., Hyttiä-Trees, E., Lähteenmäki, L., Hielm, S., Ahvenainen, R. & Korkeala, H. Thermal processing and nisin in inhibition of non-proteolytic *Clostridium botulinum* type B in sous vide cooked meat products. Manuscript.

Other dissemination (congresses, seminars, training courses)

Invited lectures:

1. Mattila-Sandholm, T. & Skyttä, E., The role of lactic acid bacteria as protective cultures. Proc. 2nd Eur. Symp. Sous vide, Leuven, 10–12 April 1996, 210–221.

Posters

1. Hyttiä, E., Skyttä, E., Morkkila, M., Kinnunen, A., Lindström, M., Ahvenainen, R. & Korkeala, H. 1999. The safety of sous-vide processed products in relation to growth and toxin production by non-proteolytic *Clostridium botulinum*. Proceedings of the Third European Symposium on Sous Vide, 25–26 March, ALMA Sous Vide Competence Centre, Leuven, Belgium, 131–132 (poster)
2. Lindström, M., Morkkila, M., Skyttä, E., Hyttiä-Trees, E., Hielm, S., Ahvenainen, R. & Korkeala, H. 1999. Safety of sous vide processed ground beef and pork cubes with respect to non-proteolytic *Clostridium botulinum* type B. Meeting of the Interagency Botulism Research Coordinating Committee. US Army Medical Research Institute of Chemical Defense/Neurotoxicology Branch. Orlando, Florida, 18–20 November 1999.
3. Skyttä, E., Morkkila, M., Kinnunen, A., Lähteenmäki, L., Ahvenainen, R., Lindström, M., Hyttiä-

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Summary of the project

Trees, E., Korkeala, H. 1999 Optimisation and microbiological safety improvement of sous vide cooking. Tekesin Uudistuva elintarvikeohjelman vuosiseminaari (The annual seminar of Tekes programme on Novel Foods) 13 October 1999.

Others

1. Kinnunen, A. Ennustavan mikrobiologian ohjelmat ja HACCP (Computer-based programmes on predictive microbiology and HACCP). Meijeri- ja lihateollisuuden hygieniapäivä (Hygiene day for dairy and meat industry), VTT, Espoo, 19 March 1997, oral presentation.
2. Skyttä, E. Mikrobiologinen turvallisuus elintarvikkeiden minimaalisessa prosessoinnissa (Microbiological safety in minimal processing of foods). Keveät keinot elintarvikkeiden prosessointiin. Minimal processing-tutkimusohjelman vuosiseminaari (Mild methods for processing of foods. The annual seminar of the Research Programme on Minimal Processing), VTT, Espoo, 26 November 1996, oral presentation.

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Summary of the project

The title of the project NOVEL PROCESSING AND COOKING METHODS FOR THE FOOD INDUSTRY		Project leader Arvo Kinnunen	
Timetable (Planned duration and person months) 1.3.1997–31.3.1998, 6 pm		Timetable (Actual duration and person months) 1.3.1997–30.6.1998, 10 pm	
Project group Raija Ahvenainen, Chief Research Scientist Arvo Kinnunen, Research Scientist Mirja Mokka, Senior Research Scientist		Chairman of the management committee Director Markku Raevuori, Meat Research Institute, Hämeenlinna	
Budget x 1000 FIM 300		Actual costs x 1000 FIM 452	
Financing from VTT x 1000 FIM (%) 272 (69%)	Tekes/MMM x 1000 FIM (%) 180 (31%)	EU x 1000 FIM (%)	Companies x 1000 FIM (%)
Industrial partners		Partners from research institutes	
<p>Objectives of the project</p> <p>The aim of the project was to critically evaluate novel processing and cooking methods with respect to the needs of the Finnish food industry.</p>			
<p>Main achievements of the project</p> <ul style="list-style-type: none"> The most important novel technologies can be divided into thermal and non-thermal technologies. The thermal technologies include infrared, microwave and radiofrequency heating, ohmic heating and direct steam injection. Non-thermal technologies include membrane and high pressure technologies, high electric pulses, ultrasound, light pulses and oscillating magnetic fields. New thermal technologies, especially ohmic heating and direct steam injection, provide better or new product quality properties based on even temperature distribution. Microbial inactivation is based on heat effects and is at a high level because of the even temperature distribution throughout the product. The non-thermal methods can provide new fresh-like product properties. Microbial inactivation is based on injuries in cell walls or breakdown of biological macromolecules, such as ribosomes and enzymes. These phenomena are very local, which means that some of the microbes always survive. Spores are unaffected by most non-thermal technologies. According to the results of an enquiry sheet and interviews most thermal methods are regarded as useful by the Finnish food industry. Most popular were infrared, microwave and ohmic heating. High pressure technology and pulsed light attracted most interest among the non-thermal methods. Optimization of the present production processes is regarded as the most important development need. 			
<p>Profit made from the achievements</p> <ul style="list-style-type: none"> The project has increased the knowledge of novel technologies within the Finnish food industry. The results have also emphasized differences in product development and product properties compared with traditional food technology. Especially health aspects, fresh-like products and semi-finished products without heat treatment can be better taken into consideration when using novel 			

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Summary of the project

technologies. This will lead to new ways of thinking about the product chains from the producer to the consumer.

Further research needs and prospects. New projects started based on this reported project.

Before the implementation of novel technologies, adaptability of raw materials and better or new product properties must be demonstrated. Several discussions between the Finnish food industry and VTT Biotechnology have shown that there is substantial interest in the food industry in the area, but unfortunately insufficient resources to start new projects at the moment. However, the aim is to start a demonstration project for the utilisation of high electric pulses, ultrasound and light pulses using meat, vegetables, milk and beer as raw materials.

Cooperation discussion with Berlin Technical University and prof. Dietrich Knorr was also initiated. A research scientist from VTT visited the Food Technology Laboratory of Berlin Technical University on 29 June - 3 July 1999.

Publications (also manuscripts)

Professional publications

1. Kinnunen, A. & Mokka, M. 1999. Uudet prosessointimenetelmät - uudenlaiset elintarvikkeet? (Novel processing - new-like foodstuffs)?. Kehittyvä elintarvike 10, No 2, 16-17.
2. Kinnunen, A., Mokka M. & Ahvenainen R. 1998. Elintarvikkeiden uudet prosessointi- ja kypsennysmenetelmät (Novel processing and cooking methods for the food production.). Helsinki: Tekes, Teknologia katsaus 63/98. 52 p.

Other dissemination (congresses, seminars, training courses)

Posters

1. Mokka, M., Kinnunen, A. & Ahvenainen, R. 1999. Potential of new cooking and processing technologies in the Finnish food industry. Eur. Conf. Emerging Food Science and Technology, 22-24 November 1999, Tampere. European Federation of Food Science and Technology, p. 101.
2. Kinnunen, A. & Mokka, M. Elintarviketeollisuuden uudet prosessointi ja kypsennysmenetelmät (Novel processing and cooking methods for the food industry.). Tekesin Uudistuva elintarvike-ohjelman seminaari (The seminar of Tekes Food Research Programme on Novel Foods) 6 May 1998.

Annual seminars

1. Kinnunen, A. & Mokka, M. Uudet kypsennys- ja prosessointimenetelmät - edut ja mahdollisuudet (Novel cooking and processing methods - advantages and possibilities). Minimal processing-tutkimusohjelman vuosiseminaari 'Keveät keinot elintarvikkeiden prosessointiin' (The annual seminar of the Research Programme on Minimal Processing), VTT, Espoo, 19 November 1997, oral presentation.

Others

1. Kinnunen, A. Uudet kypsennys- ja prosessointimenetelmät - edut ja mahdollisuudet (Novel cooking and processing methods - advantages and possibilities). Seminaari Kalavalmisteiden hygienia, prosessointi ja pakkaaminen. (The seminar Hygiene, processing and packaging of fish products). 9 April 1999. Oral presentation.
2. Kinnunen, A. Projektin tiedotusseminaari (Project dissemination seminar) 26 August 1998.

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Summary of the project

The title of the project DEVELOPMENT AND PRACTICAL IMPLEMENTATION OF NOVEL COMBINATIONS OF NISIN WITH OTHER BIOPRESERVATIVES AND MILD PROCESSES THAT EXPAND THE RANGE OF APPLICATION OF THE BACTERIOCIN IN ASSURING FOOD SAFETY AND QUALITY (NISINPLUS) (FAIR-CT96-1148)		Project leader Tiina Mattila-Sandholm (in Finland)	
Timetable (Planned duration and person months) 1.10.1996–31.12.1999, 39 pm		Timetable (Actual duration and person months) 1.10. 1996–31.12.1999, 45 pm	
Project group <u>Scientists:</u> Raija Ahvenainen, Chief Research Scientist Hanna Alakomi, Research Scientist Ilkka Helander, Senior Research Scientist Kyösti Latva-Kala, Research Scientist Tiina Mattila-Sandholm, Research Professor Maria Saarela, Senior Research Scientist Eija Skyttä, Research Scientist <u>Technician</u> Päivi Lepistö, Anu Miettinen, Aila Tuomolin		Chairman of the management committee Dr. Eddy Smid, Agrotechnological Research Institute (ATO), Wageningen, The Netherlands	
Budget x 1000 FIM 2 500		Actual costs x 1000 FIM 2 407	
Financing from VTT x 1000 FIM (%) 1 250 (50%)	Tekes/MMM x 1000 FIM (%)	EU x 1000 FIM (%) 1 250 (50%)	Companies x 1000 FIM (%)
Industrial partners Golden Vale, Charleville, Ireland Arla R&D, Stockholm, Sweden Food Safe, Winwick, U.K. Johma Nederland B.V., Losser, The Netherlands Nature's Best, Duleek, Ireland		Partners from research institutes Agrotechnological Research Institute, Wageningen, The Netherlands Federal Research Center for Nutrition, Karlsruhe, Germany Rijkszuivelstation, Melle, Belgium University of Wales at Cardiff, U.K.	
Objectives of the project <ul style="list-style-type: none"> • The objective of this EU project was to expand the range of practical applications of the bacteriocin nisin, by combination with other biopreservatives or mild processing treatments. Research at VTT was focused on the permeabilization studies of Gram-negative target organisms and experimental studies in food-mimicking matrices and commercial food products. The project was linked with several other projects in the Programme. • Permeabilization was studied in Gram-negative bacteria which are naturally nisin-resistant. A range of food-grade substances which could weaken the outer membrane (OM) were screened for their capability to sensitize Gram-negative bacteria to nisin. An array of methods revealing alterations in permeability was applied. Measurement of NPN- uptake by a fluorescent technique became the main method for general screening of permeabilizers. • In parallel to the screening of potential permeabilizers, experiments were carried out in food-mimicking matrices, utilizing combinations of nisin and natural substances inhibiting the growth of various food pathogens and spoilage organisms. Nisin was studied in combination with siderophores, organic acids, essential oil components and lysozyme. In food matrices (meat, fish, fruit juice) the effect of nisin was also studied in combination with mild preservation techniques, including sous vide processing, modified atmosphere packaging and Ultra High Pressure treatment (UHP). 			
Main achievements of the project New knowledge was obtained in the following contexts: <ul style="list-style-type: none"> • Among the permeabilizers screened (cationic permeabilizers, chelators, essential oil components, 			

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Summary of the project

organic acids, parabens, sucrose mono- and distearate, sucrose laurate), the most effective in sensitizing Gram-negative cells to nisin were some chelators (EDTA, hexametaphosphate, citric acid). Essential oil components, carvacrol and thymol are phenolic substances which were also shown to degrade OM.

- The requirement for an agent capable of sensitizing Gram-negative bacteria to nisin in order to bring about outer membrane disruption by massive chelating activity and by anionic character.
- The ability of small hydrophobic molecules to penetrate and act on Gram-negative bacteria via the porin pathway explains their membrane-disrupting properties and possible synergistic action with nisin.
- Lactic acid, although not sensitizing bacteria to nisin in an experimental setting, could play an important role in the antimicrobial character of natural products containing lactic acid.
- Nisin is incapable of affecting yeast protoplasts, indicating that the yeast cell membrane cannot be made to act as a target for nisin.
- Surprisingly, pretreatment with nisin can stabilize Gram-negative bacteria, making them more resistant to additional hurdles such as organic acids and phenolics.
- In the food-mimicking matrices studied, synergistic effects were observed between a) nisin and siderophores on *S. typhimurium*, b) nisin and thymol on *B. cereus* and *L. monocytogenes*, c) nisin and lactic acid on *L. monocytogenes* and d) nisin and citric acid on *L. monocytogenes*.
- In combination with UHP treatment the effect of nisin on *Bacillus cereus* was negligible. No further benefit was obtained if nisin was combined with lactic acid or citric acid.
- In the minimal processing of fresh fish and fish products, combination of nisin, acetic acid and modified atmosphere packaging was most promising. However, acetic acid had a harmful effect on sensory quality.
- Possibly due to instability of nisin in sous vide processing, the risk of growth of *Clostridium botulinum* was not decreased by nisin treatment.
- In a marinated meat product packed under modified atmosphere, the combination of nisin and a high concentration of CO₂ was beneficial for the microbiological stability.

Profit made from the achievements

- Accumulation of data from a wide array of potential substances tested for their Gram-negative bacterial OM-permeabilizing activity, and conclusive evidence for distinct mechanisms underlying the permeation effects.
- New methodology developed for the permeabilization studies.
- The ability of nisin to alter the response of Gram-negative bacterial cells to OM-degrading compounds can possibly be utilized.
- No clear evidence was obtained of the potential of nisin in the food applications studied. However, in marinades for meat products nisin could be used as an additional hurdle.

Further research needs and prospects. New projects started based on this reported project.

- The role of nisin as a cell protectant for Gram negative bacteria should be further studied.

Publications (also manuscripts)

Scientific publications

1. Helander, I.M. & Mattila-Sandholm, T. 2000. The permeability barrier of the Gram-negative bacterial outer membrane with special reference to nisin. *International Journal of Food Microbiology*. In press.
2. Helander, I.M. & Mattila-Sandholm, T. 2000. Fluorometric assessment of Gram-negative bacterial permeabilization. *Journal of Applied Microbiology* 88, 213–219.
3. Alakomi, H-L., Skyttä, E., Saarela, M., Mattila-Sandholm, T., Latva-Kala, K. & Helander, I.M. 2000. Lactic acid permeabilizes Gram-negative bacteria by disrupting the outer membrane. *Applied and Environmental Microbiology* 66, No 5, 2001–2005.

VTT Research Programme on Minimal Processing of Foods

Summary of the project

4. Helander, I.M., Alakomi, H.-L., Latva-Kala, K., Mattila-Sandholm, T., Pol, I., Smid, E.J., Gorris, L.G.M. & A. von Wright. 1998. Characterization of the action of essential oil components on Gram-negative bacteria. *Journal of Agricultural and Food Chemistry* 46, 3590–3595.
5. Helander, I.M., Latva-Kala, K. & Lounatmaa, K. 1998. Permeabilizing action of polyethyleneimine on *Salmonella typhimurium* involves disruption of the outer membrane and interactions with lipopolysaccharide. *Microbiology* 144, 385–390.
6. Helander, I.M., Kilpeläinen, I. & Vaara, M. 1997. Phosphate groups in lipopolysaccharides of *Salmonella typhimurium* rfaP mutants. *FEBS Letters* 409, 457–460.
7. Helander, I.M., Alakomi, H., Latva-Kala, K. & Koski, P. 1997. Polyethyleneimine is an effective permeabilizer of Gram-negative bacteria. *Microbiology* 143, 3193–3199.

Professional publications

1. Helander, I.M., von Wright, A. & Mattila-Sandholm, T.-M. 1997. Potential of lactic acid bacteria and novel antimicrobials against Gram-negative bacteria. Review article. *Trends in Food Science & Technology* 8, 146–150.

Other dissemination (congresses, seminars, training courses)

Posters

1. Helander, I.M., Alakomi, H.-L., Skyttä, E., Saarela, M. & Mattila-Sandholm, T. Lactic acid exhibits specific permeabilizing activity towards Gram-negative bacteria. American Society for Microbiology, 99th General Meeting, Chicago, Ill., 30 May - 3 June 1999.
2. The above poster was also presented at the Sixth Symposium on Lactic Acid Bacteria, Veldhoven, The Netherlands, 19–23 September 1999.
3. Helander, I.M., Alakomi, H., Latva-Kala, K. & Koski, P. 1997. The outer membrane of *Salmonella typhimurium* is effectively permeabilized to antibiotics and detergents by polyethylenimine. *Salmonella and Salmonellosis*, 20–22. May 1997, Ploufragan, France.

Invited Lectures

1. Helander, I., Cell wall of gram negative bacteria. Seminar on Industrial biological preservation of foods - theory, applications and legal aspects. 10–11 June 1998. Science Park, Aarhus, Denmark.
2. Helander, I.M. Breaking the permeability barrier of the Gram-negative bacterial outer membrane. Food Micro '99, Veldhoven, The Netherlands, 13–17 September 1999.
3. Helander, I.M. Aspects of permeabilization of Gram-negative bacteria to nisin. Bacteriocins: Progress in Food Application and Regulatory Aspects, Hørsholm, Denmark, 7–9 November 1999.
4. Helander, I. 1997. How can the Gram-negative bacterial outer membrane be permeabilized. Forschungszentrum Borstel, Germany, 26 September 1997.

Annual seminars

1. Helander, I. Nisiinin mahdollisuudet turvallisuuden varmistamisessa. Minimal processing-tutkimusohjelman vuosiseminaari 'Keveät keinot elintarvikkeiden prosessointiin' (The annual seminar of the Research Programme on Minimal Processing), VTT, Espoo, 19 November 1997, oral presentation.
2. Mattila-Sandholm, T. Biologiset keinot säilöntäaineiden vähentämisessä (Biological methods for reduction of preservatives). Keveät keinot elintarvikkeiden prosessointiin. Minimal processing-tutkimusohjelman vuosiseminaari (Mild methods for processing of foods. The annual seminar of the Research Programme on Minimal Processing), VTT, Espoo, 26 November 1996, oral presentation.

VTT Research Programme on Minimal Processing of Foods Summary of the project

The title of the project THE TEXTURE AND SHELF-LIFE OF BERRY PRODUCTS		Project leader Karin Autio	
Timetable (Planned duration and person months) 1.1.1995–31.12.1997, 19 pm		Timetable (Actual duration and person months) 1.1.1995–31.12.1997, 19 pm	
Project group <u>Scientists:</u> Karin Autio, Chief Research Scientist Kirsti Henriksson, Research Scientist Tuomo Kiutamo, Research Scientist Kati Randell, Research Scientist Martina Stolt, Research Scientist Marjaana Suutarinen, Research Scientist <u>Technicians:</u> Liisa Änäkäinen,		Chairman of the management committee	
Budget x 1000 FIM 795		Actual costs x 1000 FIM 795	
Financing from VTT x 1000 FIM (%) 795 (100%)	Tekes/MMM x 1000 FIM (%)	EU x 1000 FIM (%)	Companies x 1000 FIM (%)
Industrial partners -		Partners from research institutes -	
Objectives of the project			
<ul style="list-style-type: none"> To study and clarify those quality factors which are responsible for gelation of pectin. The combined effects of pectin, calcium and hydrochloric acid concentrations and cooking time and cooling rate on the gelation of an LM-pectin gel were examined. The recipe and the process variables were varied in the experiments in the centre of the experimental design. To study the texture of commercial jams with an Instrumental Texture Analyser (TA.XT2) and to determine those attributes of the instrumental texture profile analyses that correlate with sensory quantitative description analyses (QDA). To study the microstructure of strawberries in order to obtain knowledge about the chemical composition of strawberry tissues and the proportional amounts of chemical compounds in different parts of the tissues. 			
Main achievements of the project			
<ul style="list-style-type: none"> Satisfactory models were obtained for storage modulus ($R^2 = 0.97$), phase angle ($R^2 = 0.86$), hardness ($R^2 = 0.93$) and pH ($R^2 = 0.99$). All the recipe variables significantly influenced the storage modulus, hardness and pH of the gels. The phase angle was not affected by the pectin concentration. Interactions between the variables were important when studying the gelation of an LM-pectin gel. The cooking time and the cooling rate alone had no effect on the measured properties, but their interaction term significantly influenced the storage modulus. Sensory quality descriptive analysis (QDA) proved to be an effective method for analysing and comparing sensory profiles of commercial jams. Amounts of strawberries, degree of fragmentation of strawberries in jams and firmness of jam berries and media caused the main differences in structure between jams. About instrumental texture attributes, chewiness explained better the sensory firmness of jam mediums than did hardness or guminess. The correlation was better when using a measuring speed of 1 mm/s than at 10 mm/s. The correlation factor between instrumental chewiness and sensory firmness of jam media was 0.81. 			

VTT Research Programme on Minimal Processing of Foods

Summary of the project

- Methods based on bright-field microscopy and FT-IR microspectrometry were developed for analysing the microstructure of strawberries.

Profit made from the achievements

The basic microstructural studies provided a basis for investigation of the effects of different prefreezing treatments on the structure of strawberry tissues.

Further research needs and prospects. New projects started based on this reported project.

The effects of different prefreezing treatments on strawberry tissues after thawing and jam making. The 3-year project 'Enhancement of the industrial use of Finnish strawberries' was started at the beginning of 1998 (see the summary of the project, Appendix 8).

Publications (also manuscripts)

Scientific publications

1. Stolt, M. Factors that affect the structure of starwberry jam. Master's Thesis, University of Technology, Espoo, 20 May 1997. 109 p.
2. Suutarinen, J., Änäkäinen, L. & Autio, K. 1998. Comparison of light microscopy and spatially resolved fourier transform infrared (FT-IR) microscopy in the examination of cell wall components of starwberries. Lebensmittel Wissenschaft und Technologie 31, 595–601.

Professional publications

1. Henriksson, K., Randell, K. & Autio, K. 1996. Rakenne tärkeä hillon laatutekijä. Ttexture is an important quality factor for jams). Kehittyvä Elintarvike 7, No 4, 30–32.

Other dissemination (congresses, seminars, training courses)

1. Autio, K. Marjavalmisteen rakenne (The texture of berry products). Marjojen ja kasvien teemapäivä VTT:llä. (R&D theme day of berries and vegetables at VTT). VTT, Espoo, Finland 2 October 1996.
2. Flair-Flow seminar, VTT Biotechnology and Food Research, Espoo, Finland 24 June 1996.

VTT Research Programme on Minimal Processing of Foods
Summary of the project

The title of the project ENHANCEMENT OF THE INDUSTRIAL USE OF FINNISH STRAWBERRIES		Project leader Mirja Mokka	
Timetable (Planned duration and person months) 2.1.1998–31.12.2000, 39 pm		Timetable (Actual duration and person months) Still continues	
Project group <u>Scientists:</u> Raija-Liisa Heiniö, Senior Research Scientist Kaisu Honkapää, Research Scientist Sirpa Karppinen, Research Scientist Tuomo Kiutamo, Research Scientist Helena-Liukkonen Lilja, Senior Research Scientist Marika Lyly, Research Scientist Mirja Mokka, Senior Research Scientist Annikka Mustranta, Senior Research Scientist Martina Stolt, Research Scientist Marjaana Suutarinen, Research Scientist <u>Technicians:</u> Anne Ala-Kahrakuusi, Pirkko Nousiainen, Liisa Änäkäinen, Ulla Österlund		Chairman of the management committee Juhani Hvitfelt, Lännen Tehtaat Oyj	
Budget x 1000 FIM 1724		Actual costs x 1000 FIM	
Financing from VTT x 1000 FIM (%) 545 (31.6 %)	Tekes/MMM x 1000 FIM (%) 700 (40.6 %)	EU x 1000 FIM (%)	Companies + others x 1000 FIM (%) 479 (27.8 %)
Industrial partners Lännen Tehtaat Oyj, Saarioisten Säilyke Oy, Valio Oy, Pakkasmarjo Oy, Maustaja Oy, Oy Aga Ab, Hedelmän- ja marjanviljelijäin liitto ry, Kotimaiset Kasvikset ry, Suomen Sokeri Oy, Sisä-Savon Marjaosaamiskeskus		Partners from research institutes	
Objectives of the project The aim of the project was to promote the industrial use of domestic strawberries by developing the quality and quality management of Finnish frozen strawberries and strawberry jams. The effects of different treatments, processing stages and conditions on the quality of strawberries were studied. Particularly prefreezing treatments of strawberries were developed in order to improve the texture of jam strawberries.			
Main achievements of the project <ul style="list-style-type: none"> • The rate of freezing was found to be a more important factor affecting the quality of frozen and thawed strawberries than the rate of melting. Quick freezing with nitrogen damaged the texture of strawberries less than slow freezing. The time of harvesting and the cultivar also had a great influence on post-freezing quality of strawberries. • The prefreezing treatment of strawberries in a vacuum in solutions containing calcium chloride and pectin methylesterase (PME) stabilized strawberry tissues and affected pectin, proteins and structural carbohydrates. Firmness of frozen and particularly of jam strawberries pretreated with CaCl₂ and PME in a vacuum was higher than the firmness of untreated berries. The sensory quality of the jam when using this treatment was also better compared to other jams. • The use of sucrose in pretreatment may also have a positive effect on strawberry quality. • Bright field microscopy and FT-IR microspectroscopy were found to be useful tools for analysing the pretreatment effects in the different chemical components and their changes in strawberry tissues. 			

VTT Research Programme on Minimal Processing of Foods

Summary of the project

Profit made from the achievements

- Knowledge of factors affecting the quality of industrial strawberry products has increased.
- The calcium chloride and PME treatments in a vacuum before freezing improve the quality of especially jam strawberries.
- The pretreatment of strawberries must be performed soon after harvesting and before freezing. This may give domestic strawberries a competitive advantage against imported strawberries if the pretreatment process is applied here in Finland.

Further research needs and prospects. New projects started based on this reported project.

The project still continues. The prefreezing treatment of strawberries will be optimized during the final year of the project.

Publications (also manuscripts)

Scientific publications

1. Suutarinen, J., Honkapää, K., Moss, P. & Autio, K. 2000. The effect of calcium chloride and sucrose prefreezing treatments on the structure of strawberry tissues. *Lebensm. Wiss. Technol.* 33, 89–102.
2. Suutarinen, J., Honkapää, K., Heiniö, R.-L., Autio, K. & Morkkila, M. 2000. The effect of different prefreezing treatments on the structure of strawberries before and after jam making. *Lebensm. Wiss. Technol.* 33, 188–201.

Patents and patent applications

1. Suutarinen, J., Heiska, K. & Morkkila, M. Process for preparing jam. Patent application No 19992315. 27 October 1999. 18 p.

Other dissemination (congresses, seminars, training courses)

Posters

1. Suutarinen, J., Honkapää, K. & Autio, K. 1999B. Light microscope and spatially resolved fourier transform infrared (FT-IR) microspectrometer in the examination of the effect of CaCl₂ and pectinmethylesterase (PME) treatments on the structure of strawberry tissues in *Improved traditional foods for the next century*, F. Toldrá, D. Ramón and J.L. Navarro (Eds.), p. 127–132. Gráficas Barrastil, ISBN 84–920942–3, Valencia, Spain.
2. Suutarinen, J., Honkapää, K., Autio, K. & Morkkila, M. 2000. The effect of CaCl₂ and PME prefreezing treatment in a vacuum on the structure of strawberries. 4th Int. Strawberry Symposium 9–14 July 2000, Tampere, Finland.

VTT Research Programme on Minimal Processing of Foods

Summary of the project

The title of the project ANTIBACTERIAL PACKAGING MATERIALS		Project leader Atte von Wright/Raija Ahvenainen	
Timetable (Planned duration and person months) 1.1.1996–31.12.1998, 15 pm		Timetable (Actual duration and person months) 1.1.1996–31.12.1999, 15 pm	
Project group <u>Scientists:</u> Raija Ahvenainen, Chief Research Scientist Päivi Myllärinen, Research Scientist Thea Sipiläinen-Malm, Senior Research Scientist Eija Skyttä, Research Scientist Atte von Wright, Senior Research Scientist		Chairman of the management committee	
Budget x 1000 FIM 670		Actual costs x 1000 FIM 670	
Financing from VTT x 1000 FIM (%) 670 (100%)	Tekes/MMM x 1000 FIM (%)	EU x 1000 FIM (%)	Companies x 1000 FIM (%)
Industrial partners		Partners from research institutes	
<p>Objectives of the project</p> <p>The project was a so-called feasibility study.</p> <ul style="list-style-type: none"> The main aim was to investigate possibilities to combine antimicrobial compounds produced by selected bacteria (lactic acid bacteria, siderophore producers) with both synthetic and edible films in such a way that the biological activity of the antimicrobial compounds is maintained. The sub-aims were to study the state of the art and commercial situation of antibacterial materials and to evaluate the interest in packaging material companies in allocation of research resources for development of antibacterial packaging materials. <p>If this feasibility study had been successful, the ultimate aim would have been to start a R&D project with the industry.</p>			
<p>Main achievements of the project</p> <ul style="list-style-type: none"> In some experiments, antimicrobial compounds produced by bacteria were combined with starch-based edible films in such a way that the films prevented the growth of spoilage and pathogenic bacteria. However, the results were variable, and it was noted that the viability of bacteria producing antibacterial compounds and the ability of the bacteria to produce antibacterial compounds are key issues. This result is very important for all R&D projects in which bacteria producing antibacterial compounds are utilized for different purposes. The purpose was to prepare a patent application, but sufficient successful examples of the ideas to combine bacterial antimicrobials with synthetic materials were not obtained. For this reason, attempts to draw up a patent application were abandoned. The results obtained are therefore not public. The state of the art of antibacterial packaging materials was surveyed. At the same time, new ideas on compounds possible to combine with synthetic materials as well as combination methods were created. The development of antibacterial packaging materials is very challenging and there are many problems to be solved. The present legislation and rules concerning packaging materials and migration limits can even hinder the development of antibacterial materials if the purpose is migration of preservatives from packaging material to packed food. The institute received financial support from the EU for the 3-year ACTIPAK - FAIR- project (CT 98-4170): Evaluating Safety, Effectiveness, Economic-Environmental Impact and Consumer Acceptance of Active and Intelligent Packagings (1999–2001), in which the main aim is to make suggestions for amendments to the present packaging material legislation in the EU. 			

VTT Research Programme on Minimal Processing of Foods

Summary of the project

- Several discussions with national and foreign packaging and food companies were held. Interest in the development of antibacterial packaging materials is huge for several reasons: reduction of preservatives in food, allocation of preservatives precisely on the food, possibilities to avoid declaration of used preservatives on the package label, etc.

Profit made from the achievements

- Much basic know-how on the complexity of antibacterial packaging materials and their development was achieved.
- Knowledge of the problems due to the viability of bacteria producing antibacterial compounds was obtained.

Further research needs and prospects. New projects started based on this reported project.

- In strategic discussions at VTT, development of antibacterial materials has been selected as one of the future topics in packaging research. Discussion on cooperation with other VTT institutes (e.g. Chemical Technology) has been initiated. The purpose is to prepare a project application to Tekes. Tekes allocated funding for the preparation of this project in the spring 2000.
- In the spring of 2000, a project application on antibacterial packaging materials was prepared to the EU 5th Framework Programme. The coordinator of this proposal is The Royal Veterinary and Agricultural University, Centre for Advanced Food Studies, Denmark. The proposal was favourably evaluated by the Commission. Accordingly, the Commission services wish to proceed to contract negotiations on this proposal.

Publications (also manuscripts)

The report 'Ahvenainen, R., Alakomi, H., Helander, I., Skyttä, E. & Sipiläinen-Malm, T. 1999. Hurdle concept in food preservation. Technical report, Nordic network on Minimal Processing, 26 pp' is containing one chapter 3.3 *Antimicrobial packaging materials* based on the state-of the art survey carried out in this project.

Other dissemination (congresses, seminars, training courses)

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VTT Research Programme on Minimal Processing of Foods
Summary of the project

The title of the project ACTIVE, EDIBLE FILMS AND COATINGS		Project leader Päivi Myllärinen	
Timetable (Planned duration and person months) 1.1.1996–31.12.1996, 28 pm		Timetable (Actual duration and person months) 1.1.1996–31.12.1996, 31 pm	
Project group <u>Scientists:</u> Raija Ahvenainen, Chief Research Scientist Päivi Myllärinen, Research Scientist <u>Technicians:</u> Jaana Lehtinen, Heljä Heikkinen		Chairman of the management committee Leo Junkkarinen, Valio Oy	
Budget x 1000 FIM 1015		Actual costs x 1000 FIM 1015	
Financing from VTT x 1000 FIM (%) 327 (32 %) The rest 18 % was financed by MTT	Tekes/MMM x 1000 FIM (%) 505 (50 %)	EU x 1000 FIM (%)	Companies x 1000 FIM (%)
Industrial partners Valio Oy Oy Fazer Ab		Partners from research institutes Agricultural Research Centre of Finland (MTT), Food Technology	
Objectives of the project			
<p>The project was a preliminary study. The general aim was to collect basic information on edible films and coatings and to evaluate possibilities to minimize food packaging using active edible coatings.</p> <p>The sub-aims were: 1) comparison of technology and the properties of starch- and milk-based films, 2) to perform a case study with a few food products, 3) the start-up of a product development project.</p>			
Main achievements of the project			
<p>A publication containing</p> <ul style="list-style-type: none"> • critical literature review of the edible film and coating technology, • a survey of the commercial situation in Japan and USA by TEKES (literature and interviews), • industrial interviews, • classification of the mechanical and permeability properties of starch and milkprotein films, • a case study with cake and cheese. 			
Profit made from the achievements			
<ul style="list-style-type: none"> • Good knowledge about the situation in Japan and USA concerning the use of edible films in the food industry. • Experimental results about the suitability of starch- and milk protein-based edible coatings in real food applications (In the literature this kind of information is almost totally lacking). The shelf-life and the sensory properties of a coated cake could be enhanced for up to 8 weeks. • Development of the technology (cast film & spray techniques for applications). • The Finnish food industry was very interested in the application of edible coatings for various purposes (e.g. to prevent moisture migration). 			

VTT Research Programme on Minimal Processing of Foods Summary of the project

Further research needs and prospects. New projects started based on this reported project.

- Edible films and coatings can be used in both foods and medicines. Coatings may increase the shelf-life, retarding migration of moisture, gases, oils and fats. They can also improve the structural integrity or handling properties of foods. Antimicrobials can be added to edible films to retard the growth of yeasts, moulds and bacteria. Antioxidants or ingredients that prevent colour changes can also be added. Films can be coated on food but they can also exist as continuous layers between compartments of the same food product.
- On the basis of the work carried out, at least three (3) confidential research and development projects have been started with food companies.
- The knowledge obtained has also been utilized in several projects of the Research Programme on Minimal Processing, e.g. for potato and fish products, and in the VTT Research Programme on Future Foods for further new applications, e.g. encapsulation of probiotics.

Publications (also manuscripts)

Professional publications

1. Myllärinen, P., Rantamäki, P., Latva-Koivisto, J. & Ahvenainen, R. 1997. Elintarvikepakkausten minimointi aktiivisilla syötävillä päällysteillä. Mahdollisuudet ja haasteet. (Minimization of food packaging using active edible coatings. Possibilities and challenges). VTT Tiedotteita-Research Notes 1840, 68 pp.
2. Ahvenainen, R., Myllärinen, P. & Poutanen, K. 1997. Prospects of using edible and biodegradable protective films for foods. The European Food & Drink Review - Summer 1997, p. 73-80.

Other dissemination (congresses, seminars, training courses)

Invited lectures

1. Ahvenainen, R., Myllärinen, P. & Poutanen, K. 1997. Biodegradable and edible protective film packaging. Future packaging needs of minimally processed foods. In: Morton, I.D. & Spring, J. A. (Eds). Minimal Processing of Food: A Challenge for Quality and Safety. Conference Papers. European Federation of Food Science and Technology (EFFOST), 6 pp.

Annual seminars

1. Myllärinen, P. Pakkauksen minimointi syötävillä päällysteillä - mitä mahdollisuuksia? (Minimization of packaging by edible coating - which possibilities?). Keveät keinot elintarvikkeiden prosessointiin. Minimal processing-tutkimusohjelman vuosiseminaari (Mild methods for processing of foods. The annual seminar of the Research Programme on Minimal Processing), VTT, Espoo, 26 November 1996, oral presentation.

VTT Research Programme on Minimal Processing of Foods

Summary of the project

The title of the project IMPROVEMENT OF THE POST-HARVEST QUALITY OF STRAWBERRIES		Project leader Mirja Mokkila	
Timetable (Planned duration and person months) 1.1.1995–31.12.1997, 21 pm (VTT BEL)		Timetable (Actual duration and person months) 30.1.1995–31.3.1998, 39 pm (VTT BEL)	
Project group <u>Scientists:</u> Raija Ahvenainen, Chief Research Scientist Mari Eilamo, Research Scientist Arvo Kinnunen, Research Scientist Anna-Leena Lamberg, Student Kyösti Latva-Kala, Research Scientist Eira Laurila, Research Scientist Helena Liukkonen-Lilja, Senior Research Scientist Mirja Mokkila, Senior Research Scientist Kati Randell, Research Scientist, <u>Technicians:</u> Anu Aasmaa, Heidi Eriksson, Anuleena Kuvaja, Kirsi Norberg, Heli Nykänen, Anna-Liisa Ruskeepää, Raila Syrjänen, Anne Takkinen, Ulla Österlund		Chairman of the management committee Prof. Erkki Kaukovirta, University of Helsinki	
Budget x 1000 FIM 1325 (VTT), 1927 (total)		Actual costs x 1000 FIM 1938 (VTT), 2363 (total)	
Financing from VTT x 1000 FIM (%) 772	Tekes/MMM x 1000 FIM (%) 1050	EU x 1000 FIM (%) -	Companies + others x 1000 FIM (%) 541
Industrial partners Pakenso Oy, UPM Pack, Leppävirran Marjaosuuskunta, Pakkasmarja Oy, Suonenjoki, Hedelmän- ja Marjanviljelijäin liitto ry, W.R. Grace Oy, Oy Aga Ab, Morus Oy, Kotimaiset Kasvikset ry, Sisä-Savon Marjaosaamiskeskus, Finnvacuum Oy		Partners from research institutes VTT Building Technology, Agricultural Research Centre of Finland (MTT): Food Research, Resource Management Research / Ekological production, Agricultural Engineering Research	
Objectives of the project The aim of the project was to identify the main factors affecting the post-harvest quality of strawberries and to develop methods that could be used to prolong the shelf-life and improve the quality.			
Main achievements of the project <ul style="list-style-type: none"> • Both the shelf-life and sell by-date have been prolonged significantly as a result of the project. • The shelf-life varies depending on the crop season, the time of picking, the degree of ripeness and the variety of strawberry picked. • In optimisation of the quality and shelf-life of strawberries, attention must be paid to every phase of the life of the strawberry, from picking to consumption. • The most critical factor influencing post-harvest quality is the temperature of strawberries. Two different kinds of forced air-cooling systems that are practicable at farms were constructed and tested. • MA-packaging was found to be one of the means by which the shelf life of strawberries can be improved. 			
Profit made from the achievements <ul style="list-style-type: none"> • Knowledge of the factors that affect the post-harvest quality of strawberries has increased amongst farmers and other parties involved in the strawberry business in Finland. Most of all they have 			

VTT Research Programme on Minimal Processing of Foods

Summary of the project

become very aware of the importance of cooling and the control of temperature during storage and transport. Many farmers have invested in forced air cooling systems during recent years.

- Some marketing and delivery companies have started to pay higher prices to farmers for pre-cooled strawberries.
- In 1998 Kesko Oy, which is one of the biggest wholesalers in Finland, introduced quality guaranteed Star+ strawberries. Star+ strawberries are handled in the same way as recommended in the project: picked carefully directly into the selling package, cooled to below 10°C and stored and transported at 2°C. In the markets Star+ strawberries are stored in a cold store and selling at a cold counter is recommended.

Further research needs and prospects. New projects started based on this reported project.

- When a prolonged shelf-life of strawberries is essential, for example in export, new methods would be needed. Modified atmosphere packaging was found to be a promising method to prolong the shelf life of strawberries but more research is still needed.
- A new project 'Enhancement of the industrial use of Finnish strawberries' was started in 1998 (see the project summary, Appendix 8)
- A discussion in the national research programme concerning the development of the whole value chain of strawberries was started with the Agricultural Research Centre, industry and other representatives of the strawberry chain.

Publications (also manuscripts)

Scientific publications

1. Lamberg, A.-L. Pakkaustavan vaikutus mansikan säilyvyyteen (The effect of packaging on the shelf life of strawberries). M. Sc. Thesis. Helsinki: Helsingin yliopisto, 1997. 96 pp. + attachments. 32 p. (EKT-sarja 1132)

Professional publications

1. Mokkila, M. 1999. Avaintekijät mansikan korjuunjälkeisessä käsittelyssä (The key factors in the postharvest treatment of strawberries). Puutarha Vol 99, No 4, p. 210–211.
2. Mokkila, M. 1997. Uudet lajikkeet säilyttävät makunsa (New varieties keep their taste). Puutarha & kauppa Vol. 1, No 15, p. 18–19.
3. Mokkila, M. 1997. Tuoreen mansikan laatuun voi vaikuttaa (You can contribute to the quality of fresh strawberries). Maaseudun tulevaisuus 5.7.1997, p. 2.
4. Mokkila, M. 1998. Pakkaustekniikan mahdollisuudet mansikan tuoreuden säilyttäjänä (Possibilities of the packaging technologies to keep the freshness of strawberries). Puutarha & kauppa Vol. 2, No 19, p. 13–15.

Monographs

1. Mokkila, M., Sariola, J. & Hägg, M. 1999. Mansikan korjuun ja korjuunjälkeisen käsittelyn avaintekijät (The key factors in the harvest and postharvest treatments of strawberries). Espoo: VTT, VTT Tiedotteita - Research Notes 1955. 51 p. + app. . ISBN 951-38-5433-7.

Other dissemination (congresses, seminars, training courses)

Congress posters:

1. Hägg, M., Häkkinen, U., Mokkila, M., Randell, K. & Ahvenainen, R. 1999. Postharvest quality of strawberries. *In: Agri-Food Quality II. Quality Management of Fruits and Vegetables.* Hägg, M., Ahvenainen, R., Evers, A.M. & Tiilikkala, K. (Eds). Cambridge, UK: Royal Society of Chemistry, 142–145.

VTT Research Programme on Minimal Processing of Foods

Summary of the project

2. Mokkila, M., Lamberg, A.-L., Häkkinen, U., Kinnunen, A., Latva-Kala, K. & Ahvenainen, R. 1999. The effect of modified atmosphere packaging on the shelf life of strawberries. *In: Agri-Food Quality II. Quality Management of Fruits and Vegetables.* Hägg, M., Ahvenainen, R., Evers, A.M. & Tiilikkala, K. (Eds). Cambridge, UK: Royal Society of Chemistry, 167–170.
3. Mokkila, M., Randell, K., Hägg, M., Häkkinen, U. & Ahvenainen, R. 1996. Improvement of the postharvest quality of strawberries. Minimal Processing of Food – A Challenge for Quality and Safety. GDL / EFFoST Conference, 6.–8.11. 1996, Cologne, Germany.
4. Mokkila, M., Randell, K., Sariola, J., Hägg, M. & Häkkinen, U. 1996. Improvement of the postharvest quality of strawberries. NJF-seminar nr. 260, Postharvest i frukt og bær, 23.–24.1.1996, Åse, Norja, NJF-utredning/rapport, No. 108, 61–65.
5. Mokkila, M., Randell, K., Sariola, J., Hägg, M. & Häkkinen, U. 1997. Improvement of the postharvest quality of strawberries. 3rd Int. Strawberry Symp., Veldhoven, 29 April–4 May 1996. *Acta Horticulturae*, Vol. 2, No 439, 553–557.

Congress paper:

1. Mokkila, M., Häkkinen, U., Hägg, M., Randell, K. & Laurila, E. 1999. The quality and shelf life of some new Finnish strawberry varieties. *In: Agri-Food Quality II. Quality Management of Fruits and Vegetables.* Hägg, M., Ahvenainen, R., Evers, A.M. & Tiilikkala, K. (Eds). Cambridge, UK: Royal Society of Chemistry, 110–114.

Invited lectures

1. Mokkila, M., Uusien mansikkalajikkeiden säilyvyys (The shelf life of new strawberry varieties). 17. Hedelmän- ja marjanviljelyn talviluentopäivät, 11.–13.3.1997, Helsinki, 6 p.
2. Mokkila, M., Pakkaustekniikan mahdollisuudet mansikan tuoreuden säilyttäjänä (Possibilities of the packaging technologies to keep the freshness of strawberries). 18. Hedelmän- ja marjanviljelyn talviluentopäivät, 10.–12.3.1998, Helsinki, 4 p.

Seminars

1. Mokkila, M., Mansikan korjuunjalkeinen käsittely. (The post-harvest treatment of fresh strawberries). Marjojen ja kasvien teemapäivä VTT:llä. (R&D theme day of berries and vegetables at VTT). VTT, Espoo, Finland 2.10.1996

Video:

Antere, J. (käsikirjoitus ja ohjaus) Hyvästi mössömansikka (Goodbye mush strawberries). Helsinki: Kotimaiset Kasvikset ry, 20 min (Puutarhavidet).

4 public reports and 10 lectures held in the courses for strawberry farmers

VTT Research Programme on Minimal Processing of Foods Summary of the project

The title of the project FAIR CT96-1104: NOVEL HIGH OXYGEN AND NOBLE GAS MODIFIED ATMOSPHERE PACKAGING (MAP) FOR EXTENDING THE QUALITY SHELF-LIFE OF FRESH PREPARED PRODUCE		Project leader Riitta Kervinen	
Timetable (Planned duration and person months) 1.9.1996–31.8.1999, 61 pm		Timetable (Actual duration and person months) 1.9.1996–31.8.1999, 69 pm	
Project group <u>Scientists:</u> Raija Ahvenainen, Chief Research Scientist Riitta Kervinen, Research Scientist Eira Laurila, Research Scientist Tiina Luoma, Research Scientist Jukka Vainionpää, Senior Research Scientist <u>Technicians:</u> Anne Ala-Kahrakuusi, Pirkko Nousiainen, Nina Sandell		Chairman of the management committee Mr. Brian Day, Campden & Chorleywood Food Research Association (CCFRA), Chipping Campden, UK	
Budget x 1000 FIM 2561		Actual costs x 1000 FIM 2680	
Financing from VTT x 1000 FIM (%) 1200 (44.7%)	Tekes/MMM x 1000 FIM (%) 160 (6%)	EU x 1000 FIM (%) 1320 (49.3%)	Companies x 1000 FIM (%)
Industrial partners Saarioinen Oy		Partners from research institutes Campden & Chorleywood Food Research Association, Chipping Campden, UK SIK, Gothenburg, Sweden ATO-DLO, Wageningen, The Netherlands University of Limerick, Limerick, Ireland Istituto Nazionale della Nutrizione, Rome, Italy	
Objectives of the project The objective of the project was to find antibrowning treatments based on chemical, physical and/or biological methods to substitute sulphiting agents in fresh prepared potatoes. This project was part of the above mentioned EU-project, and only the results obtained at VTT are reported in this context.			
Main achievements of the project <ul style="list-style-type: none"> • It was shown that sulphite dipping can be replaced by other procedures in the potato processing industry. When non-sulphite dips are used, some industrial practices have to be changed. The unit operations needed depend on the type of potato process. There are two principally different potato processes: <ul style="list-style-type: none"> • Processes in which potatoes are peeled, dipped and packed, and delivered to either retail shops, catering or food manufacturers. • Processes in which potatoes are peeled, dipped and cut for further processing. Potatoes are susceptible to enzymatic browning during delays between unit operations. • In the above-mentioned situations the same non-sulphite substances can be used, but different concentrations or dipping times are needed. Several acids, such as malic acid, combined with ascorbic acid (AA) inhibited browning efficiently, whereas the commercial browning inhibitors tested were less effective even at higher concentrations. • When non-sulphite substances are used, longer dipping times are needed in comparison to dipping treatment in sodium disulphite. 			

VTT Research Programme on Minimal Processing of Foods

Summary of the project

- After non-sulphite dipping, packaging of potatoes under oxygen-free modified atmosphere is necessary. Packaging must be carried out immediately after dipping treatment. The best results are obtained under 80 N₂ + 20 % CO₂. High-oxygen modified atmosphere (75 % O₂ + 25 % CO₂) packaging generally causes colour deterioration and dry and starchy appearance. The disadvantage of vacuum packaging is the occasional formation of dark brown stripes on potatoes. However, vacuum packaging works for potatoes which are not susceptible to browning. Once packages are opened after storage, discoloration of non-sulphite dipped potatoes starts immediately in air. To avoid the discoloration after opening of the packages, the potatoes must be cooked immediately or immersed in cold water.
- The results showed that after various dipping treatments it is very important to evaluate the overall potato quality. In many experiments of this project the colour of all potato samples was acceptable but either taste or texture was remarkably changed.
- Peeling method (carborundum, knife blade, steam and hand peeling) had a remarkable effect on overall potato quality, especially on texture. A knife-peeling system developed to resemble hand-peeling as closely as possible would most probably decrease problems in texture and improve potato colour and microbiological quality.

Profit made from the achievements

- It was shown that sulphite dipping can be replaced by other procedures in browning prevention of pre-peeled potato. Several variables, such as potato lot, physiological age of the potato, peeling method, dipping treatment and packaging method were shown to affect overall potato quality.
- On the basis of the results, optimal conditions in each potato process can be defined.

Further research needs and prospects. New projects started based on this reported project

- Developing peeling method: knife peeling system resembling hand peeling as much as possible would be ideal.
- The use of both starch based edible coatings and enzymes was shown to decrease browning but these methods still need intensive research.
- Methods for browning prevention in food processing plants where potatoes are not packed after dipping treatment, but are used for further processing should be still developed. The problem in these kind of processes is enzymatic browning during the delays between unit operations.
- Several small scale potato processors and controlling authorities have made enquiries concerning browning inhibition and shelf life of pre-peeled potatoes. One project with a small scale potato peeler was carried out during the spring 2000. Particularly, an education project on the handling of pre-peeled potatoes for SME should be initiated.
- Two (2) EU-project applications on minimal processing of vegetables were prepared in the autumn 1999 for the second call of the 5th Framework Programme. The short titles of the projects are Novel MAP Plus (coordinated by CCFRA) and HurdlePack (coordinated by ATO-DLO).
- One (1) project application was prepared in the autumn 1999 for Ministry of Agriculture and Forestry. The title of the project is 'Management of quality and safety of minimally processed vegetables by novel methods'. The project was approved by Ministry. It is cooperation project between VTT, MTT, Helsinki University and vegetable chain.

VTT Research Programme on Minimal Processing of Foods

Summary of the project

Publications (also manuscripts)

Scientific publications

1. Ahvenainen, R., Hurme, E.U., Hägg, M., Skyttä, E. & Laurila, E. 1998. Shelf-life of pre-peeled potato cultivated, stored and processed by various methods. *Journal of Food Protection*, vol. 61, No. 5, 591–600.
2. Laurila, E., Hurme, E. & Ahvenainen, R. 1998. Shelf-life of sliced raw potatoes of various cultivar varieties - substitution of bisulphites. *Journal of Food Protection*, vol. 61, No. 10, 1363–1371.
3. Laurila, E., Kervinen, R. & Ahvenainen, R. 1998. The inhibition of enzymatic browning in minimally processed vegetables and fruits. Review article. *Postharvest News and Information*, vol. 9, No. 4, 53–66.
4. Hägg, M., Häkkinen, U., Kumpulainen, J., Ahvenainen, R. & Hurme, E. 1998. Effects of preparation procedures, packaging and storage on nutrient retention in peeled potatoes. *Journal of Science of Food and Agriculture*, Vol. 77, 519–526.

Professional publications

1. Ahvenainen, R. 1997. Kuorittu peruna on herkkä tuote. (Pre-peeled potato is a sensitive product). *Tuottava Peruna* 24, No 4, 20–22.

Other dissemination (congresses, seminars, training courses)

Invited lectures

1. Ahvenainen, R., Hurme, E., Skyttä, E. & Luoma, T. Perunan laadun varmistaminen kuorinnan jälkeen ja mikrobiologinen laatu. (The quality management and microbiological quality of pre-peeled potato). Suomen Perunaseura, Talviseminaari 1996 (Finnish Potato Association, Winter Seminar 1996), Seminaarin esityksiä ja alustuksia, Suomen Perunaseuran julkaisu n:o 1/1996, 15 p.
2. Ahvenainen, R. 1999. Ascertain the effectiveness of non-sulphite dips at inhibiting discoloration of prepared produce under various novel map conditions. The 4th Novel Gases MAP Club meeting, CCFRA, Gloucestershire, 12 January 1999.
3. Kervinen, R. 1999. Browning inhibition of peeled potato. Potato technology seminar for potato growers and small and medium size potato processors, 19 March 1999, Isojoki, Finland .
4. Kervinen, R. 1998. Non-sulphite browning inhibition. Presentation in the seminar “Post harvest technologies for fruits and vegetables”, VTT, Espoo, Finland, 10–11 September 1998.

Annual seminars

1. Kervinen, R. Kasvisten ja hedelmien raakatumumisen estäminen ilman sulfiittikäsittelyä. (The prevention of enzymatic browning of vegetables and fruits). Minimal processing-tutkimusohjelman vuosiseminaari 'Keveät keinot elintarvikkeiden prosessointiin' (The annual seminar of the Research Programme on Minimal Processing) 19 November 1997, VTT, Espoo, oral presentation.

VTT Research Programme on Minimal Processing of Foods

Summary of the project

The title of the project NOVEL PACKAGING METHODS FOR DOMESTIC VEGETABLES		Project leader Tuija Lyijynen	
Timetable (Planned duration and person months) 1.3.1998–30.6.1999, 12 pm		Timetable (Actual duration and person months) 1.3.1998–30.6.1999, 17 pm	
Project group <u>Scientists:</u> Tuija Lyijynen, Research Scientist Raija Ahvenainen, Chief Research Scientist Tiina Luoma, Research Scientist <u>Technicians:</u> Anne Ala-Kahrakuusi, Heli Nykänen, Nina Sandell, Pirkko Nousiainen and Ulla Österlund,		Chairman of the management committee Harto Ylitalo, Pyhäjärvi Institute	
Budget x 1000 FIM 520		Actual costs x 1000 FIM 520	
Financing from VTT x 1000 FIM (%) 200 (38.5 %)	Tekes/MMM x 1000 FIM (%) 260 (Tekes, 50 %)	EU x 1000 FIM (%)	Companies x 1000 FIM (%) 60 (11.5 %)
Industrial partners Oy AGA Ab Kotimaiset Kasvikset ry Ab Rani Plast Oy Euran Vihanneskeskus Oy Isokaski ky		Partners from research institutes Agricultural Research Centre of Finland / Häme Research Station	
Objectives of the project The project was a preliminary study. The main object of the study was to obtain information on the suitability of modified atmosphere packages, various active packaging systems and different packaging materials for the retail packaging of Finnish fresh onion (no pre-drying), Chinese cabbage, broccoli, cauliflower and carrot. The aim was also to identify the most important variables of modified atmosphere packaging and storage and to determine the dependence of the shelf-life and quality of vegetables on these variables.			
Main achievements of the project <ul style="list-style-type: none"> • Vegetables should be sold with a protective wrap, because without it they exhibit loss of weight and freshness. The current packaging of vegetables should be improved. The packaging material and the storage temperature affected the shelf-life of the vegetables examined (iceberg lettuce, broccoli, fresh onions and carrots). The oxygen transmission rate of the packaging material and the storage temperature had the most significant effect on the shelf-life of packed vegetables. During storage, the quality of the vegetables was best described by sensory characteristics, such as the odour of opened packages and the appearance and texture of the vegetables. • All the vegetables had the best shelf-life in the packaging material with moderate permeability to oxygen or in the lightly perforated packaging material. The oxygen-tight packaging material caused off-odours in the vegetables. The optimal gas mixture for vegetable packaging contains 5–15 % oxygen and 5–10 % carbon dioxide. Broccoli and carrots have the best shelf-life at 2–4 °C, onions at 2 °C and iceberg lettuce at 4–6 °C. The results for fresh onions were especially promising: the shelf-life of the onions was 3 months in cold storage at 2 °C. The onions had begun to form roots and sprouts at the end of the storage, but this did not affect the use of the onions. • Argon or nitrous oxide in the packaging gas, absorbers (ethylene or carbon dioxide) and different pre-packaging washing solutions did not significantly increase the shelf-life of vegetables. Washing with water was sufficient. 			

VTT Research Programme on Minimal Processing of Foods

Summary of the project

Profit made from the achievements

- The results showed that vegetables should not be stored and/or sold without any wrapping.
- The shelf-life of vegetables can be increased with the correct package type and storage temperature.
- For example, Finnish fresh onions and broccoli can be sold for longer into the autumn, and the fresh harvest does not have to be sold at a low price at short notice.
- The packaged fresh onions are very easy to use and they have a long shelf-life.

Further research needs and prospects. New projects started based on this reported project.

- The bulk packaging of Finnish fresh vegetables.
- One new project has been submitted and approved by the Ministry of Agriculture and Forestry: The Management of quality and safety of raw vegetable products by novel processing and packaging techniques.

Publications (also manuscripts)

One report (= the final report) of the results of the project was distributed to the project partners. The report is public and is not published in any VTT series. The report is freely available at only the cost of copying.

Professional publications

1. Ahvenainen, R. 2000. Laatu ja säilyvyyttä kasviksille uusilla prosessi- ja pakkausmenetelmillä. (Improved quality and shelf-life of vegetables by novel processing and packaging methods). Kehittyvä elintarvike 11, No. 2, 14–15.

Two articles to Finnish gardening journals (manuscript).

Other dissemination (congresses, seminars, training courses)

Invited lectures

1. Ahvenainen, R. MAP research activities at VTT. Seminar on Modified atmosphere packaging - An update. 12 March 1999. SIK, Gothenburg, Sweden.
2. Lyijynen, T. Pakkaamisen vaikutus parsakaalin säilyvyyteen. (The effect of packaging on the shelf-life of broccoli). Parsakaalipäivä (Broccoli day) 23 March 2000, Pyhäjärvi Institute, Kauttua.
3. Lyijynen, T. Pakkaamisen vaikutus kasvisten säilyvyyteen. (The effect of packaging on the shelf-life of vegetables). Vihannesten laatuketjun parantaminen (Improvement of vegetable chain). 28 March 2000, Pyhäjärvi Institute, Kauttua.

Posters

1. Lyijynen, T., Luoma, T. & Ahvenainen, R. 2000. Shelf-life of some vegetables in novel MA and active packages, Agricontrol 2000 -congress 10–12 July 2000, Wageningen, the Netherlands.

Others

1. Lyijynen, T. Kotimaisten kasvisten uudet pakkausratkaisut. (New packaging solutions for domestic vegetables) Kasvisseminaari (Vegetable seminar) 2 September 1999, VTT Biotechnology and Food Research, Espoo.

**VTT Research Programme on Minimal Processing of Foods
Summary of the project**

The title of the project NORDFOOD PROJECT 93113: FISH, TRANSPORT AND PACKAGING/RETAIL PACKAGING OF FISH AND FISH PRODUCTS		Project leader Raija Ahvenainen	
Timetable (Planned duration and person months) 1.1.1994–31.12.1997, 29 pm		Timetable (Actual duration and person months) 1.1.1994–31.12.1997, 27 pm	
Project group <u>Scientists:</u> Raija Ahvenainen, Chief Research Scientist Kati Randell, Research Scientist Tapani Hattula, Research Scientist Eija Skyttä, Research Scientist Tuija Lyijynen, Student and Research Scientist <u>Technicians</u> Taina Holm, Aila Tuomolin, Ulla Österlund, Heidi Eriksson, Pirkko Nousiainen, Eeva Manninen, Heli Nykänen		Chairman of the management committee <u>In Nordic level:</u> Helge Bergslien, Norconserv, Norway <u>In Finland:</u> Raimo Hautala, Suomen Kalakauppiasliitto	
Budget x 1000 FIM 1000		Actual costs x 1000 FIM 1031	
Financing from VTT x 1000 FIM (%)	Tekes/MMM x 1000 FIM (%) 709 (via Suomen Kalakauppiasliitto) (69%)	NI x 1000 FIM (%) 205 (19.9%)	Companies x 1000 FIM (%) 70 (6.8%)
Industrial partners <u>In Nordic countries:</u> Seven (7) companies from Denmark Three (3) companies from Sweden Four (4) companies from Iceland Eight (8) companies from Norway <u>In Finland:</u> Suomen Kalakauppiasliitto and members Oy Aga Ab Enso-Gutzeit Oy Lahti Mills United Papermills Ltd.		Partners from research institutes Else Marie Andersen/Dansk Institut for Fiskeri Teknologi, Denmark Sveinn Vikingur Arnason/Icelandic Fisheries Laboratories, Iceland Helge Bergslien/Norconserv, Norway Oskar B. Hauksson/Technological Institute of Iceland, Iceland	
Objectives of the project <u>The aims of the Nordic project were</u> <ul style="list-style-type: none"> to strengthen the Nordic fishing industry with respect to export by proposing optimal effective distribution and packaging conditions and thereby guaranteeing high product quality, to provide the fish industry with an analysis and documentation of how to choose the optimal packaging and distribution system, both at present and also with respect to more strategic solutions in the near future. <p><u>The aims of the research carried out at VTT (Sub-project 'Retail packaging of fish and fish products') were</u></p> <ul style="list-style-type: none"> to develop saleable, environmentally friendly and profitable retail packaging systems giving a good shelf-life for fresh fish and fish products, to prepare status- and scenario reports together with other Nordic research institutes participating in Nordfood project. 			
Main achievements of the project (mainly only achievements in the sub-project 'Retail packaging of fish and fish products' at VTT are described) <ul style="list-style-type: none"> Status- and scenario reports together with other Nordic research institutes. 			

VTT Research Programme on Minimal Processing of Foods

Summary of the project

- Execution of retail packaging studies in two (2) transport experiments with Norwegian salmon from Norway to Finland. Transport experiments were carried out together with Norconserv. The cooperation with Norconserv was fruitful and constructive. A traditional polystyrene foam transport box with ice was found to be as good as novel modified atmosphere packaging systems (MAP) as a transport packaging system. The advantage of MAP, however, was the decreased use of ice compared to that in polystyrene boxes. With regard to retail packaging, MAP gave the best shelf-life for filleted salmon. Furthermore, the best shelf-life for salmon was obtained when salmon was filleted immediately after harvesting and packed in retail packages using modified atmosphere.
- Environmentally friendly wood fiber trays and polyester-coated mini-corrugated board trays were as suitable as traditional styrofoam trays for tray in wrap-retail packaging.
- Optimized modified atmosphere packaging systems (optimized gas composition, head-space volume and packaging materials) for retail packaging of filleted Baltic herring, rainbow trout, perch and pike-perch.
- Information on shelf-lives of filleted perch and pike-perch in various potential retail packaging systems: foamed polystyrene tray + wrap, mini-corrugated board tray + wrap, vacuum package, modified atmosphere packaging, packaging with carbon dioxide emitter and oxygen absorber. The two latter packaging methods gave the best shelf-life.
- Hygiene and packaging guide for the fish industry, VTT Research Notes 1847.

Profit made from the achievements

Due to the effective dissemination of results to the Finnish fish industry (several information meetings were organised and the hygiene and packaging guide was prepared),

- fish companies learned the advantages and disadvantages of each available retail and transport packaging systems,
- fish companies gained much practical information about how to implement different packaging technologies, e.g. modified atmosphere packaging.

The project also demonstrated the importance of good hygiene and initial quality for the shelf-life of packed fish and fish products. Packaging gives the greatest benefit when the fish to be packed is freshly caught and treated hygienically.

Further research needs and prospects. New projects started based on this reported project.

Combination of various dipping and coating technologies with novel packaging technologies in order to improve the safety and shelf-life of fish products. A new project 'Improvement of the shelf-life and safety of fresh fish and fish products with minimal processing methods' was started at the beginning of 1997. See the project summary (Appendix 15).

Publications (also manuscripts)

Scientific publications

1. Lyijynen, T. Ahven- ja kuhafileiden säilyvyys erilaisissa vähittäispakkauksissa. (The shelf-life of perch and pike-perch fillets in various retail packagings). Master's Thesis, University of Technology, Espoo, 1 October 1996. 138 p + app. 13.
2. Randell, K., Ahvenainen, R. & Hattula, T. 1995. Effect of the gas/product ratio and CO₂-concentration on the shelf-life of MA-packed fish. *Packaging Technology and Science* 8, 205–218.
3. Randell, K., Hattula, T. & Ahvenainen, R. 1997. Effect of the packaging method on the quality of rainbow trout and Baltic herring fillets. *Lebensmittel Wissenschaft und Technologie* 30, No 1, 56–61.

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Summary of the project

4. Sivertsvik, M., Rosnes, J. T., Vorre, A., Randell, K., Ahvenainen, R. & Bergslien, H. 1999. Quality of whole gutted salmon in various bulk packages. *Journal of Food Quality*, 22, 387–401.
5. Randell, K., Hattula, T., Skyttä, E., Sivertsvik, M., Bergslien, H. & Ahvenainen, R. 1999. Quality of filleted salmon in various retail packages. *Journal of Food Quality*, 22, 483–497.

Professional publications

1. Ahvenainen, R. & Randell, K. 1995. Kalan vähittäispakkaamista tutkitaan NORDFOOD-projektissa. (Retail packaging of fish is studied in a NORDFOOD-project). *Pakkaus* 31, No 4, 56–58.
2. Ahvenainen, R. 1995. Kalan kuljetusta ja pakkaamista tutkitaan pohjoismaisessa NORDFOOD-ohjelmassa. (Transport and packaging of fish are studied in the Nordic NORDFOOD programme). *Kala-Fisk* N:o 1/95, 6.
3. Randell, K., Lyijynen, T. & Ahvenainen, R. 1996. Kalan kuljetuksesta ja pakkaamisesta mielenkiintoisia tuloksia. (Interesting results on transport and packaging of fish). *Kala-Fisk* No1/1996, 4.
4. Ahvenainen, R. & Randell, K. 1997. Nordfood-projektissa suojakaasu antoi parhaan säilyvyyden pakatulle tuoreelle kalalle. (In Nordfood- project protective gas gave the best shelf-life for fresh fish). *Kala-Fisk*, No 1/1997, 8.

Monographs

1. Randell, K. & Ahvenainen, R. 1994. Retail packaging of fresh fish. VTT Research Notes 1603, Espoo, 50 p.
2. Lyijynen, T., Randell, K., Hattula, T. & Ahvenainen, R. 1997. Kalateollisuuden hygienia- ja pakkausopas, VTT Tiedotteita 1847, (Hygiene and packaging guide of fish industry, VTT Research Notes 1847) Espoo, Valtion Teknillinen Tutkimuskeskus, 73 p. + app. 5 p.

Chapters in books

1. Randell, K. & Ahvenainen, R. 1998. Optimized MA-packaging of fish for retailing. *Modern Food Packaging*. Dordi, M.C. (Ed), p. 98–114.

Other dissemination (congresses, seminars, training courses)

Research reports

Together nine (9) VTT research reports were written to the Finnish and Nordic companies participated in the project.

Proceedings

1. Ahvenainen, R. 1995. Trends and applications of modified atmosphere and active packaging systems; safety and acceptability. In: Ahvenainen, R., Mattila-Sandholm, T. & Ohlsson, T. (Eds.) *New Shelf-life Technologies and Safety Assessments*. VTT Symposium, Espoo, pp. 85–102.
2. Ahvenainen, R. 1995. Research activities and commercialisation on MAP in Scandinavia. In: *Modified Atmosphere Packaging and Related Technologies*, Campden & Chorleywood Food Research Association, Chipping Campden, 6–7 eptember 1995. 9 pp.
3. Sivertsvik, M., Vorre, A., Rosnes, J.T., Randell, K., Ahvenainen, R. & Bergslien, H. 1996. Packaging, transportation and storage of salmon (*Salmo salar*) under different atmospheres. 2nd Nordfood Conference 'Future, Culture and Know-how', 17–20 August 1996, Reykjavik, Iceland, Nordfood rapport 2: 1996, pp. 29–32. ISSN 0805–343X.

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Summary of the project

4. Randell, K., Hattula, T., Skyttä, E., Sivertsvik, M., Bergslien, H. & Ahvenainen, R. Quality of salmon in various retail packages. 2nd Nordfood Conference 'Future, Culture and Know-how', 17–20 August 1996, Reykjavik, Iceland, Nordfood rapport 2: 1996, pp. 26–28. ISSN 0805–343X.
5. Lyijynen, T., Randell, K., Kinnunen, A., Skyttä, E., Hattula, T. & Ahvenainen, R., Modeling of shelf-life of gas-packed perch and pike-perch fillets. 2nd Nordfood Conference 'Future, Culture and Know-how', 17–20 August 1996, Reykjavik, Iceland, Nordfood rapport 2: 1996, pp. 127. ISSN 0805–343X.
6. Ahvenainen, R., Lyijynen, T., Randell, K., Skyttä, E., Hurme, E. & Hattula, T. 1997. The shelf-life of perch and pike-perch fillets in different retail packages. The 3rd Nordfood Conference 'Sustainable food production and competitive industries', 23–25 November 1997, Copenhagen, Denmark, Nordfood rapport 5: 1997, pp. 78–79. ISSN 0805–343X.

Abstracts

1. Randell, K., Ahvenainen, R. & Hattula, T. Quality of smoked baltic herring in wood fibre and styrox packages. WEFTA Seafood Conference. Amsterdam 13–16 November 1995 (Abstract P3). (Poster).

Information meetings and press conference

1. Information meetings were organised about twice a year for Finnish fish companies.
2. The results were presented in the press conference organised in 2nd Nordfood Conference 'Future, Culture and Know-how', 17–20 August 1996, Reykjavik, Iceland,.

VTT Research Programme on Minimal Processing of Foods

Summary of the project

The title of the project IMPROVEMENT OF SHELF-LIFE AND SAFETY OF FRESH FISH AND FISH PRODUCTS WITH MINIMAL PROCESSING METHODS		Project leader Tuija Lyijynen	
Timetable (Planned duration and person months) 1.3.1997–31.12.1998, 21 pm		Timetable (Actual duration and person months) 1.3.1997–30.4.1999, 25 pm	
Project group <u>Scientists:</u> Raija Ahvenainen, Chief Research Scientist Tapani Hattula, Research Scientist Tiina Luoma, Research Scientist Tuija Lyijynen, Research Scientist Päivi Myllärinen, Research Scientist Eija Skyttä, Research Scientist <u>Technicians:</u> Heidi Eriksson, Jaana Lehtinen, Pirkko Nousiainen, Heli Nykänen, Nina Torttila, Aila Tuomolin, Ulla Österlund		Chairman of the management committee Raimo Hautala, Suomen Kalakauppaliitto	
Budget x 1000 FIM 830		Actual costs x 1000 FIM 890	
Financing from VTT x 1000 FIM (%) 27 (3%)	Tekes/MMM x 1000 FIM (%) 803 (MMM, 97 %)	EU x 1000 FIM (%)	Companies x 1000 FIM (%)
Industrial partners Helsingin Kalansavustamo Oy Kalaliike V. Hukkanen Kalamesta Oy		Partners from research institutes Department of Food and Environmental Hygiene /Faculty of Veterinary Medicine/University of Helsinki	
Objectives of the project The main aim of the project was to develop new, mild processing and packaging methods to improve the shelf-life, safety and nutritional quality of raw rainbow trout and Baltic herring and products made from them. Other aims were to reduce the salt content of fish products, to develop new easy-to-use consumer products and to replace preservatives with mild processing methods.			
Main achievements of the project <ul style="list-style-type: none"> • The best methods to improve the shelf-life of fish (raw rainbow trout and Baltic herring fillets) and fish products (hot-smoked rainbow trout fillets) were the edible coating and the oxygen absorber. Particularly the oxygen absorber worked very well in packages of smoked fish products. • The edible coating was sprayed or spread to the surface of the fish products. The edible coating can be added to the fish surface with sodium chloride (salt) after smoking. The inoculation test of <i>Clostridium botulinum</i> type E indicated that the edible coating with sodium chloride may have significance in reduction of the risk caused by this bacterium in smoked fish. • Different spraying and dipping treatments and novel packaging gases (e.g. argon, nitrous oxide, hydrogen and high oxygen concentration) did not essentially increase the shelf-life of fish products. The solutions tested in spraying and dipping were: various acids, nisin, one commercial product and their different combinations. One of the novel packaging gases was particularly interesting: carbon monoxide appeared to inhibit the growth of microbes. • The salt content of the smoked fish product could be decreased by reducing the soaking time in brine before smoking or by adding the salt with the edible coating after smoking. 			

VTT Research Programme on Minimal Processing of Foods

Summary of the project

Profit made from the achievements

- The study provided much information about the different minimal processing methods and their possibility to increase the shelf-life of the fish products.
- For example, the edible coating technique was suitable for the fish products. Only a few methods have previously been available to improve the safety of fish, but now the edible coating has become one of the most significant methods.
- The small fish companies should prefer to use active packages (oxygen absorber and carbon dioxide emitter), because these increase the shelf-life of fish products in comparison with the normal package (e.g. the wrap package or air/gas in the package). The active packaging method is also cheaper than the gas packaging technique.

Further research needs and prospects. New projects started based on this reported project.

- Further studies of edible coatings and of carbon monoxide in the packaging gases are needed. A properly formulated edible coating can inhibit the growth of *C. botulinum* type E and carbon monoxide may inhibit the growth of the common spoilage microbes.
- New minimal processing methods might also provide a means to decrease the growth of other risk microbes (e.g. *Listeria monocytogenes* and *Escherichia coli*).

Publications (also manuscripts)

Scientific publications

1. Lyijynen, T., Lindström, M., Luoma, T., Skyttä, E., Korkeala, H. & Ahvenainen, R. The inhibition of toxin production by *Clostridium botulinum* type E in hot-smoked rainbow trout (manuscript).

Professional publications

1. Ahvenainen, R. 1997. Tuoreen kalan ja kalavalmisteiden säilyvyyden lisääminen minimal processing-menetelmillä. (The improvement of shelf-life for fresh fish and fish products by minimal processing methods). Kala-Fisk 2/97, 2.
2. Lyijynen, T., Skyttä, E., Myllärinen, P., Luoma, T. & Ahvenainen, R. Tuoreen kalan ja kalavalmisteiden säilyvyyden lisääminen kevein keinoin. ((The improvement of shelf-life for fresh fish and fish products by mild methods). Kala-Fisk 1/98, 5.
3. Lyijynen, T., Luoma, T., Skyttä, E., Myllärinen, P. & Ahvenainen, R. Kalavalmisteiden säilyvyyden lisääminen kevein keinoin. (The improvement of shelf-life of fish products by mild methods). Kala-Fisk 2/99, 10.

Other dissemination (congresses, seminars, training courses)

Research reports

Six (6) research reports of the results of the project have been given to the project partners.

Invited lectures

1. Ahvenainen, R., Improvement of quality and safety of fish products by minimal processing and packaging. FISH'97 - FAIR Seminar Development forecasts for the international fish trade, Helsinki 21 August 1997, 4 p.
2. Luoma, T., Lyijynen, T. & Ahvenainen, R. Quality of fish products with minimal processing methods. Nordic Workshop VIII Sensory Evaluation and Quality -seminar, 9–11 September 1999, Reykjavik, Iceland.

VTT Research Programme on Minimal Processing of Foods

Summary of the project

Abstracts

1. Luoma, T., Lyijynen, T., Skyttä, E., Lähtenmäki, L. & Ahvenainen, R., Evaluating the sensory quality of minimally processed fish products. Nordic Workshop VIII Sensory evaluation and quality, 9–11 September 1999, Reykjavik, Iceland , 15.

Others

1. Lyijynen, T. 1999. Kalavalmisteiden säilyvyyden ja turvallisuuden lisääminen minimal processing -menetelmillä (The improvement of shelf-life and safety of fish products by minimal processing). Kalavalmisteiden hygienia, prosessointi ja pakkaaminen -seminaari (Hygiene, processing and packaging of fish products-seminar) 9 April 1999, VTT Biotechnology and Food Research, Espoo.
2. Lyijynen, T. 1999. Tuoreen kalan ja kalavalmisteiden säilyvyyden lisääminen minimal processing menetelmillä. KALA 99 - Kansainväliset kalamessut 20–22 August 1999, Wanha Satama, Helsinki.

VTT Research Programme on Minimal Processing of Foods
Summary of the project

The title of the project EU-FAIR CT96-1020: HARMONIZATION OF SAFETY CRITERIA FOR MINIMALLY PROCESSED FOODS (Concerted Action)		Project leader Dr. Toon Martens, a coordinator for the EU project	
Timetable (Planned duration and person months) 1996–1999, 4 pm (at VTT)		Timetable (Actual duration and person months) 1996–1999, 2 pm (at VTT)	
Project group Dr.T.Martens, ALMA Universiteitsrestaurants vzw, Dr. Kristel Hauben, ALMA Universiteitsrestaurants vzw, Dr. R. Moezelaar, Agro-technological Research Institute, Dr. G.D. Betts, Campden and Chorleywood Research Association, Dr.C.Nguyen, INRA, Station deTechnologie des Produits Végétaux, Mr.B.Morice, Fruidor Les Crudettes, Dr.J.Sheridan, TEAGASC, R.Van Havere, FOOD INSPECTION SERVICE, Prof.E.Borch, Swedish Meat Research Institute, Mrs.H.Latvalahti, European Chilled Food Federation, Dr.A.M.Sjöberg, VTT Biotechnology , Dr.M.de Fatima Filipe Poças, Escola Superior de Biotecnologia, K.Dewinter, The European Consumers' Organisation, Dr.P.Zeuthen, Technical University of Denmark, Dott.S.Quintavalla, Experimental Station for Food Preserving Industry, Mrs.E.Assimaki-Gaspari, Consumer's Association 'The Quality of Life', Mr.F.Falconnet, Mrs.S.Litman, SYNAFAP, Dr.H.Bergslien, NORCONSERV, Dr.C.Genigeorgis, Aristotle University, Dr.M.Peck, Institute of Food Research, Dr.C.Michiels, Katholieke Universiteit Leuven, Ms.C.Boissin, NESTEC Ltd., Dr. L. Gorris, Unilever Research Laboratorium, Dr. Hans-Dieter Werlein, University of Hannover, Dr. Rosa Maria Garcia-Gimeno, University of Rabanales, Dr. D. Banati, University of Horticulture and Food Industry		Chairman of the management committee Dr. Toon Martens	
Budget x 1000 FIM 85		Actual costs x 1000 FIM 85	
Financing from VTT x 1000 FIM (%) 30	Tekes/MMM x 1000 FIM (%) -	EU x 1000 FIM (%) 55	Companies x 1000 FIM (%) -
Industrial partners See above		Partners from research institutes See above	

VTT Research Programme on Minimal Processing of Foods Summary of the project

Objectives of the project

The objective was to provide a sound scientific basis for the setting of standards and regulations relating to the safe production and distribution of minimally processed foods.

Main achievements of the project

The project brought together a significant number of representatives from food processing industries, from private and governmental research organisations and from legislative and consumer organisations. Their task was to investigate the current status of safety criteria of minimally processed foods as put forward by legislative organisations, trade organisations and consumer organisations of various EU member states. An inventory of legal requirements, safety criteria, and good manufacturing practices in the European Union was published in 1997. The Inventory Report highlighted considerable differences in safety criteria which were evaluated on the basis of current scientific knowledge. During the discussions, the project group identified different areas in which further consideration or research was recommended. This information was used to discuss possible harmonized criteria for minimally processed foods. The Rational and Harmonization Report summarizes the outcome of discussions and gives recommendations for harmonized criteria. It was prepared for the benefit of food researchers, legislative authorities, food producing industries, retailers and consumer organisations. It is intended to present additional information on inconsistencies in current legislation, and possible methodologies for standardisation of safety criteria.

Profit made from the achievements

Dissemination of the two Reports on "Harmonization of Safety Criteria for Minimally Processed Foods" to the European food industry, institutes, retailers, consumer organisations and legislative authorities.

Further research needs and prospects. New projects started based on this reported project.

Not yet

Publications (also manuscripts)

Professional publications

1. Harmonization of Safety Criteria for Minimally Processed Foods: Inventory Report, 46 pp.
2. Harmonization of Safety Criteria for Minimally Processed Foods: Rational and Harmonization Report, 79 pp.

Other dissemination (congresses, seminars, training courses)

1. Meeting Management Group 09/10/96 Leuven, Belgium,
2. General Meeting 04/11/96–05/11/96 Leuven, Belgium,
3. Meeting Management Group 17/03/97 Leuven, Belgium,
4. General Meeting 9/06/97–10/06/97 Avignon, France,
5. Meeting Management Group 27/10/97 Leuven, Belgium,
6. General Meeting 15/1/98–16/1/98 Wageningen, The Netherlands,
7. Meeting Management Group 04/05/98 Helsinki, Finland,
8. General Meeting 18/11/98–20/11/98 Helsinki, Finland,
9. Meeting Management Group 05/02/99 Leuven, Belgium,
10. General Meeting 2/6/99–4/6/99 Parma, Italy
11. Latvalahti, H. Minimaalisesti prosessoitujen elintarvikkeiden turvallisuuskriteerien harmonointi EUssa. (Harmonization of safety criterias of minimally processed foods in EU), Minimal processing-tutkimusohjelman vuosiseminaari 'Keveät keinot elintarvikkeiden prosessointiin' (The annual seminar of the Research Programme on Minimal Processing) 19 November 1997, oral presentation.

VTT Research Programme on Minimal Processing of Foods Summary of the project

The title of the project NORDIC NETWORK: MINIMAL PROCESSING - PRESERVATION METHODS OF THE FUTURE		Project leader Raija Ahvenainen (in Finland)	
Timetable (Planned duration and person months) 1.7.1997–30.6.2000, 8.5 pm		Timetable (Actual duration and person months) 1.1.1996–31.12.1999, 8.5 pm	
Project group Raija Ahvenainen, Chief Research Scientist Hanna Alakomi, Research Scientist Eero Hurme, Senior Research Scientist Riitta Kervinen, Research Scientist Eira Laurila, Research Scientist Arja Laitila, Research Scientist Tiina Mattila-Sandholm, Research Professor Thea Sipiläinen-Malm, Senior Research Scientist Eija Skyttä, Research Scientist		Chairman of the management committee Prof. Thomas Ohlsson, SIK, Sweden	
Budget x 1000 FIM 510		Actual costs x 1000 FIM 510	
Financing from VTT x 1000 FIM (%)	Nordic industrifond via SIK x 1000 FIM (%) 314 (61.6%)	EU x 1000 FIM (%)	Companies x 1000 FIM (%) 196 (38.4%)
Industrial partners <u>In Finland:</u> Soile Grönman, Fazer Leipomot Oy Jukka Hallikas, Lihateollisuuden tutkimuskeskus Juhani Hvitfelt, Lännen Tehtaat Oy Maarit Kari, Perunantutkimuslaitos Merja Leino, Atria Oyj Raimo Liukko, Raisio Yhtymä Oy Marjatta Salminen, Seinäjoen ammattikorkeakoulu Ilkka Salomaa, Turun Teknillinen Oppilaitos Kari Sipilä, HK-Ruokatalo Oy <u>In other Nordic countries</u> 5 companies from Denmark, 12 companies from Norge, 9 companies from Sweden, 1 company from Iceland		Partners from research institutes Helge Bergslien, Norconserv, Norway Hannes Hafsteinnsson, Center of Food Technology, Iceland Finn Holm, FoodGroup, Denmark Thomas Ohlsson, SIK, Sweden	
Objectives of the project To initiate industrial R&D and exploitation projects utilizing minimal processing technologies, with Nordic food packaging and equipment industries, research institutes and universities as participants. This will be accomplished by actions to increase the information flow and the competence among the participants regarding the possibilities and limitations of minimal processing technologies.			
Main achievements of the project Effective information flow <ul style="list-style-type: none"> • by publishing eight (8) Newsletters, so far. One issue will still be published. VTT Biotechnology has contributed to each issue by presenting project news and know-how at VTT, • by publishing eight (8) Technical reports (monographs) on various aspects of minimal processing. VTT has been for responsible four (4) Technical reports. See the publications, 			

VTT Research Programme on Minimal Processing of Foods

Summary of the project

- by organising fourteen (14) seminars on various aspects of minimal processing. Two (2) more seminars will still be organised. VTT has been responsible for four (4) seminars and will be responsible for one (1) of those still to be held. See the Summary of the project 'Management of Minimal Processing Research Programme' and the main text of this report,
- by publishing two (2) Surveys on Market Trends. VTT was not involved in these.

Profit made from the achievements

Companies which are members of the network project have obtained much practical information about the possibilities and limitations of various minimal processing technologies for different food products. This information helps companies in decision making concerning R&D. In Finland, two professional training institutes have used information obtained from the project in their course programmes.

At the final stage of the programme, the aim is to start new R&D projects with companies at the Nordic level. This discussion is not yet finished. The project will end with the final seminar at the end of September 2000, where final decisions on new projects will be possibly made.

Further research needs and prospects. New projects started based on this reported project.

See the above

Publications (also manuscripts)

Monographs written at VTT

1. Laurila, E. & Ahvenainen, R. 1997. Post-harvest technologies. Technical report, Nordic network on Minimal Processing, 15 pp.
2. Hurme, E., Ahvenainen, R. & Nielsen, T. 1998. Active and smart packaging of foods. Technical report, Nordic network on Minimal Processing, 31 pp
3. Alakomi, H.-L., Helander, I., Laitila, A., Skyttä, E., Ahvenainen, R. & Mattila-Sandholm, T. 1999. Bacteriocins and other lactic acid bacterial antimicrobials in food preservation. Technical report, Nordic network on Minimal Processing, 17 pp.
4. Ahvenainen, R., Alakomi, H., Helander, I., Skyttä, E. & Sipiläinen-Malm, T. 1999. Hurdle concept in food preservation. Technical report, Nordic network on Minimal Processing, 26 pp.

Other dissemination (congresses, seminars, training courses)

See the main text the chapter Dissemination and the summary of the project Management of Minimal Processing Research Programme.

Lectures

Ahvenainen, R. Pohjoismainen verkostoprojekti: Minimal Processing - Preservation Methods of the Future. Minimal processing-tutkimusohjelman vuosiseminaari 'Keveät keinot elintarvikkeiden prosessointiin' (The annual seminar of the Research Programme on Minimal Processing) 19 November 1997, VTT, Espoo.

VTT Research Programme on Minimal Processing of Foods Summary of the project

The title of the project MANAGEMENT OF MINIMAL PROCESSING RESEARCH PROGRAMME		Project leader Raija Ahvenainen	
Timetable (Planned duration and person months) 1.1.1996–31.12.1998, 14 pm		Timetable (Actual duration and person months) 1.1.1996–31.12.1999, 20 pm	
Project group All projects leaders of the Programme Juha Ahvenainen, Research Director Tiina Mattila-Sandholm, Research Professor Kaisa Poutanen, Research Professor		Chairman of the management committee Prof. Juha Ahvenainen, Research Director	
Budget x 1000 FIM 980		Actual costs x 1000 FIM 1330	
Financing from VTT x 1000 FIM (%) 1330 (100 %)	Tekes/MMM x 1000 FIM (%)	EU x 1000 FIM (%)	Companies x 1000 FIM (%)
Industrial partners Juhani Hvitfelt, Lännen Tehtaat Oy Mirja Rautakoski and Maarit Kyyrö, Saarioinen Oy Raimo Hautala and Asta Nousiainen, Suomen Kalakauppiaaliitto Jouko Tikkanen and Päivi Jämsen, Kotimaiset Kasvikset ry Jukka Salminiitty, Elintarviketeollisuusliitto and Tekes since August -98 Jari Kauppila, Tekes		Partners from research institutes	
Objectives of the project <ul style="list-style-type: none"> • To manage the Programme and disseminate the contents and results of the Programme. • To evaluate the commercial need for the Minimally Processed Trademark. 			
Main achievements of the project <ul style="list-style-type: none"> • Eight (8) management committee meetings were organised. The members of the management committee were very active and cooperation was fruitful and constructive. • Six (6) national seminars were organised entirely or partly and seven (7) International Congresses and Seminars were organised partly by the Minimal Processing Programme (See the main text). • Ten (10) invited lectures and three (3) other lectures were given as part of the Programme. • Nine (9) professional publications, two (2) proceedings and five (5) proceedings papers not connected with any specific project in the Programme were written, • The Proceedings 'Hägg, M., Ahvenainen, R., Evers, A.M. & Tiilikkala, K. (Eds). 1999. Agri-Food Quality II. Quality Management of Fruits and Vegetables. The Royal Society of Chemistry, Cambridge, 377 pp.' received very good evaluations from the Aslib Book Guide, Nahrung (R. Kabbert) and Food Science and Technology Abstracts. For example, Aslib Book Guide, vol. 64, no. 8, ref. 897, August 1999 states the following: This is a collection of some ninety-five papers on agri-food quality. As such, the subject matter is very far ranging and presented to a very high technical level. At a time when human foods and production processes are experiencing an extremely high level of scrutiny from every sector, this book provides us with an excellent reference on a wide range of themes. 			

VTT Research Programme on Minimal Processing of Foods

Summary of the project

- Participation in FINPRO's publication Pure Pleasure Throughout the Finnish Food Chain - from the field to the table. (VTT participated in the minimal processing and precision packaging concepts).
- The time is not yet ripe for the Minimally Processed trademark.
- The minimal processing concept has been well adopted in industry (see, e.g. FINPRO's publication).
- The Gold Key 2000 award of the Association for Finnish Work (Suomalaisen Työn Liiton Kultainen Avain 2000 - tunnustuspalkinto) to the manager of the Programme, Dr. Raija Ahvenainen. The grounds for the award given by the jury were the following: Raija Ahvenainen is a pioneering, internationally recognised Finnish developer of pure food production chain. The grounds for the competitiveness of the food sector in Finland is pure foodstuffs, pure food products and good management of the food production chain. With her research group Raija Ahvenainen does valuable, innovative work by solving and developing novel food processing and packaging concepts in which product safety, better quality, convenience and energy saving are emphasized. The jury was led by Minister Kimmo Sasi.

Publications (also manuscripts)

Professional publications

1. Ahvenainen, R. 1996. New approaches in improving the shelf life of minimally processed fruit and vegetables. *Trends Food Sci. Technol.* 7, 179–187.
2. Ahvenainen R. 1996. Tuotannon tulevaisuus - tulevaisuuden tekniikat. (The future of the production - the technologies of the future) *Elintarvikehygienian eilen ja huomenna. 10-vuotisseminaari. (Food hygiene yesterday and tomorrow. 10 years seminar) 19.4.1996, ETS Elintarvikehygienian jaosto, Helsinki, 3 p.*
3. Ahvenainen, R. 1996. Minimal Processing - tutkimusohjelmassa kehitetään keveitä prosessimenetelmiä. (Mild processing methods are being developed in Minimal Processing Research Programme). *Kehittyvä Elintarvike*, No 3, 18–19.
4. Ahvenainen, R. & Randell, K. 1996. Kalan kulutuksen lisääminen keskeinen aihe WEFTAn kongressissa. (The increase of consumption of fish was key topic in WEFTA Conference). *Kala-Fisk* 2/96, 3.
5. Ahvenainen, R. & Hurme, E. 1997. Aktiivisista elintarvikepakkauksista uutta käytännön tietoa. (New practical information about active food packaging). *Pakkaus* 32, No 4, 12–15.
6. Ahvenainen, R. 1997. Keveät keinot elintarvikkeiden käsittelyssä pelosta pöytään. (Mild methods for food treatment from the field to the table). *Kehittyvä elintarvike* 8, No. 2, 10–12.
7. Kinnunen, A. & Ahvenainen, R. 1996. Porkkanan, kaalien ja sipulin CA- ja MA-varastointi. (CA- and MA storage of carrot, cabbage and onion). *Jokioinen Maatalouden tutkimuskeskuksen julkaisuja, Sarja A; 10. 29 pp. ISBN 951-729-473-5.*
8. Ahvenainen, R. 1997. Keveät keinot elintarvikkeiden prosessointiin. (Mild methods for processing of foods). *Tekniikan näköalat* 3, 14–15.
9. Ahvenainen, Raija. 1998. Tuoreita ja laadukkaita elintarvikkeita kevein keinoin (Fresh and good foodstuffs by mild methods). *Kotitalous* 62, No 7–8, 38–40.

Proceedings

1. Ohlsson, T., Ahvenainen, R. & Mattila-Sandholm, T. (Eds) 1996. *Proceedings of the Int. Symposium on Minimal Processing of and Ready Made Foods. 18–19 April 1996. SIK, Gothenburg, Sweden, 197 pp.*

VTT Research Programme on Minimal Processing of Foods

Summary of the project

2. Hägg, M., Ahvenainen, R., Evers, A.M. & Tiilikkala, K. (Eds). 1999. Agri-Food Quality II. Quality Management of Fruits and Vegetables. The Royal Society of Chemistry, Cambridge, 377 pp.

Commercial publications

1. FINPRO. 1999. Pure Pleasure Throughout the Finnish Food Chain - from the field to the table. (VTT participated with minimal processing and precision packaging concepts).

Other dissemination (congresses, seminars, training courses)

Proceedings

1. Ahvenainen, R. & Hurme, E. 1996. Practical guidelines for minimal processing of vegetables. in: Ohlsson, T., Ahvenainen, R. & Mattila-Sandholm, T. (Eds). Int. Symp. Minimal Processing and Ready Made Foods, 18–19 April 1996, The Swedish Institute for Food and Biotechnology, Gothenburg, pp. 31–44.
2. Mattila-Sandholm, T. 1996. Microbial methods in minimal processing. In: Ohlsson, T., Ahvenainen, R. & Mattila-Sandholm, T. (Eds). Int. Symp. Minimal processing and ready made foods, 18–19 April 1996., The Swedish Institute for Food and Biotechnology, Gothenburg 113–126.
3. Skyttä, E., Laine, M., Raaska, L., Wright von, A. & Mattila-Sandholm, T. 1996. Application of lactic acid bacteria antimicrobials against gram-negative organisms and moulds. 5th FEMS Symp. Lactic Acid Bacteria, Veldhoven, 8–12 September 1996, C3.
4. Wright von, A. 1996. Antimicrobial metabolites from lactic acid bacteria. In: Wirtanen, G., Raaska, L., Salkinoja-Salonen, M. & Mattila-Sandholm, T. (Eds), Future prospects of biofouling and biocides, Helsinki 13–14 June 1996. Espoo 1996. VTT Symposium 165, p. 45.
5. Alakomi, H.-L., Raaska, L., Tuominen, U., Lahdenperä, M.-L., von Wright, A. & Mattila-Sandholm, T. 1998. Antifungal activities of *Lactobacillus*, *Staphylococcus* and *Pseudomonas*. Proc. COST 914 & COST 915 Joint Workshop Non conventional methods for the control of postharvest disease and microbiological spoilage, Bologna, 9–11 Oct. 1997. Luxembourg: Office for Official Publications of the European Communities, 141–147.

Invited lectures

1. Ahvenainen, R. 1996. Ready-to-use Vegetables - a New Product, a New Challenge. Vortragsband of Flair-Flow workshop 'Der gesundheitliche Wert des Gemusekonsums', 6 May 1996, pp. 47–61.
2. Ahvenainen, R. 1996. Ympäristönäkökohtien huomioon ottaminen pakkausmateriaalien kehittämisessä. (Environmental aspects in development of packaging materials). Elintarvikepäivä 96, 7.5.1996. Luentolyhenteet. Elintarvikkeiden tutkimussäätiö, Helsinki, 5 pp.
3. Ahvenainen, R. 1996. Elintarvike herkullisena ruokapöytään - mitä keinoja moderni pakkaustutkimus tarjoaa. (Possibilities of modern packaging research to serve delicious foodstuffs for consumers). Pakkausalan teknologiaohjelman vuosiseminaari 22 May 1996, Dipoli, TEKES ja PTR. 17 pp.
4. Ahvenainen, R., Minimal processing-ohjelman avulla laadukkaisiin marjajalosteisiin. (Berry products of good quality by Minimal Processing research programme). Monien Mahdollisuuksien Marjat. Marjasuomi-projektin loppuseminaari 14 August 1997. Ravintola Sipuli, Helsinki (110 Participants)
5. Ahvenainen, R. 1997. Täsmäpakkaaminen vaatii monitahoista tutkimusta. (Precision packaging needs elaborate research) Tekesin Pakkausalan teknologiaohjelman vuosiseminaari 20 November 1997, Dipoli, 5 pp.
6. Mattila-Sandholm, T. & Ahvenainen, R. Minimal processing-menetelmien turvallisuus. (The safety of minimal processing methods). Elintarvikepäivät -98, 5 May 1998.

VTT Research Programme on Minimal Processing of Foods

Summary of the project

7. Ahvenainen, R. Minimal processing. Tekesin Uudistuva elintarvike-ohjelman vuosiseminaari 6 May 1998.
8. Lyijynen, T. Suojakaasupakkaamisen uudet tuulet. "Pakkaustiedot ajantasalle", Paikka: Oy AGA Ab, Espoo (puoli päivää kestävä tilaisuus), 6 October 1998 (luennoitsijat + n. 30 henk.) ja 24 November 1998 (lecturers + .32 attendants.)
9. Ahvenainen, R., Hurme, E. & Smolander, M. 1998. Active and smart packaging -novel packaging methods to assure the quality and safety of foods. In: Schenk, H. (ed.), Visions -Packaging Innovations Today and Tomorrow. SIG Pack Congress, Helsinki 3-4 September 1998. SIG Pack Systems AG, Beringen, Switzerland, pp. 94-115.
10. Mattila-Sandholm, T., VTT on lactic acid bacteria. Proc. Conf. Food Ingredients Europe, London, 4-6 November 1997. Maarssen: Miller Freeman, 1998, 92-96.

Others

1. Ahvenainen, R. Minimal processing - kuluttajan etu. Keveät keinot elintarvikkeiden prosessointiin. Minimal processing-tutkimusohjelman vuosiseminaari (Mild methods for processing of foods. The annual seminar of the Research Programme on Minimal Processing), VTT, Espoo, 26 November 1996, oral presentation.
2. Ahvenainen, R., Minimal processing - uusi näkökulma prosesseihin ja pakkauksiin. (Minimal processing - a new perspective on processes and packages). Elintarviketieteiden Seuran Tiedepäivä VTT Bio- ja elintarviketekniikassa (Scientific day of Finnish Society of Food Science and Technology at VTT Biotechnology and Food Research) 19 March 1998, oral presentation.
3. Ahvenainen, R. Minimal processing ja pakkaus (Minimal processing and packaging). Kalatalouden rakennetukirahaston vierailu VTT:llä (The visit of fish authorities at VTT) 29 October 1999, oral presentation.



Author(s) Ahvenainen, Raija, Autio, Karin, Helander, Ilkka, Honkapää, Kaisu, Kervinen, Riitta, Kinnunen, Arvo, Luoma, Tiina, Lyijynen, Tuija, Lähteenmäki, Liisa, Mattila-Sandholm, Tiina, Morkkila, Mirja & Skyttä, Eija			
Title VTT research programme on Minimal Processing. Final report			
Abstract <p>At the beginning of 1996 VTT Biotechnology started a four-year VTT Research Programme 'Minimal Processing of Foods'. In this programme new, mild, inexpensive and natural methods to improve the shelf-life and safety of foods were to be developed. The aims of the programme were to improve the sensory quality, nutritional properties and safety and increase the competitiveness of food products based on domestic raw materials.</p> <p>A total of 18 different projects were carried out in the Research Programme. Twelve projects involved research cooperation with other national or international research institutes and companies. The main topics were minimization of heat processes, development of active packaging films and improvement of the shelf-life of fresh foods. The most important technologies studied were high pressure technology, supercritical extraction, sous-vide cooking, novel gas packaging methods and materials, coating technology, utilization of protective cultures and application of nisin and other natural compounds such as organic acids, and combined methods (hurdle technology). Furthermore, the potential of various novel physical (e.g. light pulses, electric field pulses, ultrasound) and chemical methods (e.g. mustard oil, lactobionic acid, ozone) for food preservation were preliminarily surveyed.</p> <p>Strategically important in the Programme was that novel methods were studied for real and relevant foodstuffs and food raw materials, and in quality and shelf-life studies both microbiological as well as sensory quality (appearance, flavour, texture) were considered. Most of the available information in the scientific literature deals with the effects of novel methods in laboratory media, or the effects have been studied only to a limited extent, ignoring e.g. the sensory evaluation of the flavour of treated food.</p> <p>The Programme considerably increased knowledge of the possibilities of various novel process and packaging technologies to minimize the harmful effects of processes on the sensory and nutritional quality of food without microbiological safety risks. Optimized processes and recipes, combined methods and integrated approaches were found to be the most promising ways to maintain the quality and ensure the safety of foodstuffs. The significance of quality management from the field to the table or from raw material production to the consumer was emphasized in the Programme. The basics for development of active packaging materials were also created in the programme. Coating technology appeared also to have promising possibilities as a 'precision weapon' in many applications, but still needs further development. High pressure technology will have potential in some special, gourmet food products to ensure shelf-life, but also needs further development. Other novel physical and chemical methods will be promising for ensuring microbial safety and for modification of the texture of food products.</p> <p>In Finland, experimental design or predictive microbiology have hitherto been used very little in product development in the food industry. Improved procedures for optimization of processes and packages were developed in the Programme. Experimental design (e.g. surface response methodology) is an essential tool for optimization. Furthermore, process and recipe improvement is always a multi-stage procedure, in which e.g. computer-based programmes on predictive microbiology will help to reduce the number of experiments and to determine the optimal range of processing temperature and time or recipe conditions. In the Programme, this working approach was launched particularly for the meat and sous-vide industry.</p> <p>The minimal processing concept, as such, was also developed during the programme. It was clearly realized that the concept supports the idea of sustainable development and the imago of health-promoting properties of foodstuffs. From the legislative point of view minimal processing might even be an easier way to develop health-promoting foodstuffs than the approach in which health-promoting compounds are added to the food product. Some companies adopted the concept in their strategy concerning product and process development. They also simplified and optimized their processes. Public awareness about the advantages of minimal processing approach was also increased. Standardisation and legislation are important elements in the development of the minimal processing concept. The Programme took part in the EU FAIR Concerted Action CT96-1020 project 'Harmonization of safety criteria for minimally processed foods'. Recommendations and possible methodologies for standardisation of safety criteria were given in the project.</p> <p>Dissemination of the results of the projects was an essential part of the Programme. The total number of research reports from the projects of the Programme is over one hundred. Some of them are non-public. In addition to these, three annual reports and one report on a trade mark were prepared from the Programme. Altogether 26 original scientific papers have been prepared from the results of the various projects of the Programme. Furthermore, 38 professional publications in international and national magazines have been published. Eighteen invited lectures and 19 scientific posters have been delivered. The amount of other publications (monographs, lectures, processing guides, chapters in books etc.) to date is 44. In addition, one patent application on the pre-treatment of strawberries for freezing and one training video on the treatment of fresh strawberries have been prepared. Six national and seven international seminars were organised entirely or partly by the Minimal Processing Programme.</p>			
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VTT:n elintarvikkeiden Minimal Processing -ohjelma. Loppuraportti			
Tiivistelmä			
<p>Vuoden 1996 alussa VTT Biotekniikka käynnisti 4-vuotisen tutkimusohjelman 'Elintarvikkeiden Minimal Processing'. Ohjelmassa kehitettiin uusia, keveitä, edullisia ja luonnollisia menetelmiä elintarvikkeiden säilyvyyden ja turvallisuuden parantamiseksi. Ohjelman tavoitteina oli parantaa kotimaisista raaka-aineista tehtyjen elintarvikkeiden aistittavaa laatua, ravitsemuksellisia ominaisuuksia ja turvallisuutta sekä niiden kilpailukykyä. Ohjelmassa toteutettiin yhteensä 18 projektia. Kaksitoista niistä oli yhteistyöprojekteja joko kansallisten tai kansainvälisten tutkimuslaitosten ja yritysten kanssa. Projektien pääaiheina olivat lämpöprosessien minimointi, aktiivisten pakkaukskalvojen kehittäminen ja tuotetuotteiden säilyvyyden parantaminen. Tärkeimmät tutkitut tekniikat olivat korkeapainetekniikka, ylikriittinen uutto, sous-vide-kypsennys, uudet kaasupakkauksenmenetelmät ja -materiaalit, päälylystysteknologia, suojaviljelmien, nisiinin ja muiden luonnollisten yhdisteiden kuten orgaanisten happojen käyttö sekä yhdistelmätekniikat (ns. hurdle effect). Lisäksi alustavasti arvioitiin muutamien uusien fyysikaalisten (esim. valopulssit, sähköpulssit, ultraääni) ja kemiallisten (esim. sinappiöljy, laktobionihappo, otsoni) menetelmien mahdollisuuksia elintarvikkeiden säilyttämisessä.</p> <p>Keskeistä ohjelmassa oli se, että uusia menetelmiä kokeiltiin todellisille elintarvikkeille ja elintarvikeraaka-aineille ja elintarvikkeiden laatua tarkasteltiin kokonaisvaltaisesti ottamalla huomioon aistittavan laadun kaikki puolet ja mikrobiologinen säilyvyys. Suurin osa saatavilla olevasta tieteellisestä kirjallisuudesta, joka koskee uusien menetelmien vaikutuksia mm. mikrobeihin on tehty laboratorioalustoilla tai sitten menetelmän vaikutusta on tutkittu hyvin rajatusti, unohtaen esim. aistittava laatu. Siten kirjallisuudessa esitetyt tulokset ovat useimmiten liian lupaavia; aine tai menetelmä, joka toimii laboratorio-olosuhteissa ei välttämättä toimikaan enää todellisissa elintarvikkeissa. Tämä havaittiin mm. nisiinin suhteen.</p> <p>Ohjelma lisäsi huomattavasti tietämystä uusien prosessi- ja pakkaustekniikoiden mahdollisuuksista vähentää prosessien haitallisia vaikutuksia elintarvikkeiden aistittavaan ja ravitsemukselliseen laatuun ilman mikrobiologisia riskejä. Optimoidut prosessit ja reseptit, yhdistelmätekniikat ja kokonaisvaltainen laadunhallinta pelloilta (alkutuotannosta) pöytään osoittautuivat parhaimmiksi tavoiksi ylläpitää elintarvikkeiden laatua ja varmistaa niiden turvallisuus. Ohjelmassa luotiin myös perusteet aktiivisten pakkauksmateriaalien kehittämiseksi. Päälylystysteknologia osoittautui lupaavaksi ns. 'täsmäaseena' monissa sovelluksissa, mutta se tarvitsee vielä käytännön kehitystyötä. Korkeapainetekniikalla on mahdollisuuksia erikois- ja herkkuelintarvikkeiden valmistamiseksi, mutta sekin tarvitsee vielä tutkimusta. Muut uudet fyysikaaliset ja kemialliset menetelmät ovat lupaavia mikrobiologisen turvallisuuden varmistamiseen ja elintarvikkeiden rakenteen muokkaukseen.</p> <p>Suomessa koesuunnittelua ja ennustavaa mikrobiologiaa on tähän mennessä käytetty hyvin vähän elintarviketeollisuudessa. Ohjelmassa luotiinkin parantuneet menettelytavat prosessien ja pakkausten optimoimiseksi. Tietokonepohjaiset koesuunnittelumenetelmät ovat oleellinen osa optimointia. Prosessien ja reseptien parantaminen on aina monivaiheista, jolloin tietokonepohjaiset ennustavan mikrobiologian ohjelmat auttavat vähentämään kokeitten määrää ja määrittämään oikean alueen prosessointilämpötilalle ja -ajalle sekä reseptille. Ohjelmassa uudet menettelytavat lanseerattiin mm. lihateollisuuteen ja sous-vide-tuotteita valmistaviin yrityksiin.</p> <p>Minimal processing -käsite kehittyi myös ohjelman aikana. Minimal processing -ajattelu tukee kestäväää kehitystä ja terveysvaikutteisten elintarvikkeiden imagoa. Lainsäädännölliseltä kannalta minimal processing saattaa olla helpompi tapa kehittää terveysvaikutteisia elintarvikkeita kuin menettelytapa, jossa terveysvaikutteista yhdistettä lisätään elintarvikkeeseen. Eräät yritykset lanseerasivat käsitteen tuotekehityksensä strategiaan ohjelman kuluessa. Nämä yritykset myös yksinkertaistivat ja optimoivat prosessejaan. Myös yleinen tietoisuus minimal processingin eduista lisääntyi.</p> <p>Standardointi ja lainsäädäntö olivat myös tärkeitä tekijöitä minimal processingin kehittämisessä. Ohjelma otti osaa EU-projektiin CT96-1020 project 'Harmonization of safety criteria for minimally processed foods'. Projektissa annettiin suositukset ja mahdolliset menettelytavat minimaalisesti prosessoitujen elintarvikkeiden turvallisuuskriteerien standardoimiseksi EU:ssa.</p> <p>Syntyneiden tulosten levittäminen oli olennainen osa ohjelmaa. Ohjelman projekteista kirjoitettiin yli sata julkista tai ei-julkista tutkimusraporttia projektien rahoittajille ja yhteistyökumppaneille. Itse ohjelmasta valmistui johtoryhmälle 3 vuosiraporttia ja raportti tavaramerkistä. Tähän mennessä on myös valmistunut yhteensä 26 tieteellistä alkuperäisartikkelia tai opinnäytetyötä, 1 patentihakemus, 38 ammatillista julkaisua sekä kansainvälisissä että kansallisissa lehdissä ja 44 muuta julkaisua, kuten prosessioppaita sekä yksi opetusvideo. Lisäksi on pidetty 18 kutsuttua esitelmää ja esitetty 19 posteria eri tilaisuuksissa. Ohjelma oli myös joko täysin tai osittain vastuussa kuuden kansallisen ja seitsemän kansainvälisen seminaarin järjestämisestä.</p>			
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