PROJECT FINAL REPORT

Grant Agreement number: 289262

Project acronym: **STARTEC**

Project title: **D**ecision **S**upport **T**ools to ensure safe, tasty and nutritious **A**dvanced **R**eady-**T**o-**E**at foods for healthy and vulnerable **C**onsumers (STARTEC)

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Project Partners

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4.1 Final publishable summary report

4.1.1 Executive Summary

Food business operators must make daily decisions about food safety and quality, often based on limited scientific data, or full knowledge of the consequences of deviations for the consumer, due to the limited capacity to carry out scientific analyses and detailed risk assessments. The purpose of the project has been to develop the an IT tool and guidelines based on scientific evidence and predictive models to enable food operators estimate the quality and safety level in their products (ready-to-eat foods) if alternative ingredients, process and storage conditions are applied. Pathogens studied include: *Listeria. monocytogenes, Staphylococcus aureus, Salmonella enterica, Bacillus cereus, Verotoxin-producing E.coli (VTEC)* and *Clostridium* spp, as well as *Staphylococcus* toxins. The effect of high pressure treatment, dielectric heating, bio-preservation and packing technologies were investigated. Food quality and cost/benefit factors were also assessed. The project focused on normal and vulnerable consumers where increased quality and safety levels are needed, e.g. patients at nursing homes, hospitals, old and sick people living at home. The project ran for three years and involved eight participants, of which five were SMEs. Producers of convenience and RTE products were actively involved in the project as well as experts in food microbiology, food chemistry, food process technology, information technology and modelling, laboratory analytical methods, cost-benefit analysis and risk assessment.

A prototype tool for multidisciplinary decision support has been developed and validated in terms of the IT structure of the tool, relevance and user-friendliness of the user interface, and the prediction of *L. monocytogenes* of the primary and secondary models developed in the project. The tool was found conceptually correct. If further developed, the tool can help SME operators to quantify and manage spoilage and pathogen risks in a way which is not currently possible. The strongest point of the prototype tool is that it is flexible and can be adapted to: different types of food company in terms of products, processes, complexity of flow charts, etc.; any multidisciplinary aspect and model for any parameter, which can be inserted; customized categorization using a traffic light system which can be applied for normal and vulnerable consumers; use of a corrective action/support section, which can easily further developed; and new functionalities based on either the database, models or both. The tool was developed based on the needs expressed by industry partners at the beginning of the project, and based on mapping challenges and possibilities for corrective actions in industry production, wet lab studies and surveys addressing cost/benefit aspects of ready-to-(h)eat foods. The industry mapping is highly relevant as a basis for development of future decision support tools, making them more suitable for use in industry.

Deli salads were extensively studied in the project. For pasta salads with vegetables and meat, the Baranyi no lag model is well suited as a primary model for *L. monocytogenes*, while the Rosso model is a promising secondary model. For potato salads, formulations considering the dairy product in the sauce and/or late addition of heated chicken meat can be used to reduce and even eliminate the *Listeria* risk so the product can be served even to vulnerable consumers. Vitamin C is an important parameter for the nutrition value of salads. The vitamin levels are reduced if the vegetables are cooked and the products are stored in air. Among the novel technologies studied, high pressure treatment was the most promising, both because it was effective for reduction of the Listeria levels, the technology has become scalable and relatively affordable, and because it can be combined with other technologies, e.g. bio-preservation, to limit outgrowth of surviving bacteria.

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4.1.2 Project context and objectives

Food business operators make daily decisions regarding suppliers, ingredients, food formulations, process conditions, distributors and customers. Even under 'business as usual conditions' such decisions are challenging, but particularly for producers of ready-to-eat (RTE) foods, where many ingredients and processing operations are needed to produce deli salads, convenience meals and other RTE products. It is even more challenging if the preferred suppliers and ingredients are not available, if unintended deviations in process or storage conditions occur, and/or when customers demand a higher safety and quality level than the standard. Trade-offs between safety, quality and costs must be done quickly and based on very limited data regarding possible consequences of the deviations. The corrective action in cases of abuse of processing and storage conditions may be destruction, reprocessing, redirection or no action at all, depending on the quality and safety level required for the specific product and the consumer demand. Destruction of products leads to less profit and more waste, but if a product is contaminated with a pathogen that develops to an infective level because of the deviation, then the food safety risk is unacceptable. The ideal solution is to use ingredients and processes where the risks can be minimized, and also to ensure that products with possible deviations are not served to the most vulnerable consumers. To do so, the deviation has to be discovered in time, but SME providers of convenient and ready-to-eat products have limited capacity to carry out analyses and risk assessments. The objective of this project was therefore to develop tools that providers of convenient and RTE products can use in their risk assessment and decision support in daily business, in negotiations with suppliers and customers, and for in-house product and process development. Such tools will make it possible for food providers to be innovative without compromising food safety and quality. The tools will also be useful for food authorities, policy makers, researchers, risk managers and other personnel working with convenient and RTE foods.

This **three year project** involved **eight participants**, of which **five are SMEs.** The SME participants included three food producers of convenience and RTE products (Matbørsen, Kohinoor, and Forno Ramgnolo); one research-providing SME (IRIS), and one research management SME (Halbert Research). The SMEs were active in the management and research activities of the project, along with multi-disciplinary research teams from the National Veterinary Institute of Norway, Queens University Belfast, University of Bologna, as well as IRIS. The food producers are situated in Norway, Ireland, and Italy, and deliver a wide range of mixed RTE products including deli salads, full meals, and cold cuts, to supermarkets, nursing homes, hospitals, and airlines. The research partners from Norway, UK, Italy and Spain, have considerable expertise in food microbiology (food pathogenic and spoilage bacteria), food chemistry, food process technology, including preservation technology, information technology and modelling, laboratory analytical methods, cost-benefit analysis and risk assessment.

In the **first phase** of the project, the consortium investigated and established critical food safety and quality challenges that typical SME food producers deal with on a daily basis. The three SME food producers were actively involved, and their production systems were used as practical models for the research work. In the **second phase**, the research team, in collaboration with the food SMEs, investigated in laboratory experiments how the safety and quality (including storage stability and organoleptic quality) of foods develops or is affected when different ingredients (meat, seafood, dairy and vegetables) of variable quality and contamination levels are mixed in raw and heat treated RTE and convenience products. Both ideal and deviating process conditions, as well as

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abuse storage conditions during distribution and by the consumer were considered. The purpose of such studies is not only to obtain more knowledge, but also to suggest possible performance objectives (POs) and process criteria (PCs) for ingredients and production processes to ensure the required quality and safety levels of the products. The approach in this part of the project was to use the food safety objectives (FSOs) and microbial criteria for final products in the EU-legislation and estimate POs and PCs by "tracing back" to the processes and ingredients. In terms of food safety, the following pathogens were included in the study: *Listeria monocytogenes*, *Staphylococcus aureus*, *Salmonella enterica, Bacillus cereus*, Verotoxinproducing *E.coli* (VTEC) and *Clostridium* spp, with particular emphasis on *Listeria* and *Staphylococcus*, as well as *Staphylococcus* toxins. For the spoilage and food quality aspect, the approach was to develop criteria based partly on existing knowledge about limiting factors for shelf life, and partly on new analyses of specific spoilage bacteria and organoleptic analyses. Other quality parameters, being related to processing as well as to storage conditions were included; these are emulsion instability, texture deterioration, moisture related problems, microbial and non-microbial related odour development.

It can be foreseen that it will not always be possible to meet the required safety and quality level for vulnerable consumers by using standard process and preservation technology. Products with increased quality and safety levels are however needed, as patients at nursing homes, hospitals, old and sick people living at home, and so on, consume a lot of RTE and convenience products. In fact, many of them have no other choice than to eat the RTE and convenience foods they are served. These people are not only susceptible to food borne diseases, but also to under- and malnutrition. SME food providers therefore have an ethical (as well as legal) duty to make sure that products are produced, transported and stored in ways that maintain safety and quality, or at least to inform customers whether the products are suited for serving to vulnerable consumers or not. A possibility to change the process conditions to make the products safer, and thereby introduce an extra "safety switch", or correspondingly a "nutrition switch" or "quality switch", would be very useful in such cases. Therefore, in the **third phase** of the project, the possibility of obtaining a higher quality and safety level of the products was investigated, such as the use of more robust process conditions, replacement of ingredients that are not suited for tougher process conditions with more stable ones, and/or use of mild preservation methods. Novel, advanced, mild, preservation methods are often costly and typically not useful in large scale food production. At a small scale, when customised products are produced for some consumers, however, technologies like high pressure treatment, dielectric heating, bio-preservation and packing technologies may be useful, not only for food safety, but also for quality of the food. Another approach included in this part of the project is to reduce the temperature during distribution and storage of the products, or use of time-temperature indicators on the product package indicating the quality and safety level. Safety and quality parameters were evaluated in a methodical and systematic way to allow probabilistic modelling of their values with different raw materials and manufacturing processes. In this way, a database was created which led to the creation of a tool for interaction and development.

The **fourth and final phase** of the project was to develop the tools based on the scientific evidence and predictive and probabilistic models produced in the early phases of the project. The main tool is an IT based system where food providers can insert their data and estimate the quality and safety level in their products if alternative ingredients, process and storage conditions are applied. This decision making tool will enable the SME operator to quantify and manage spoilage and pathogen risks in a way which is not currently possible. A cost-benefit module in the tool, could allow the food providers to compare quality, safety and costs of their actions, for example, lowering the

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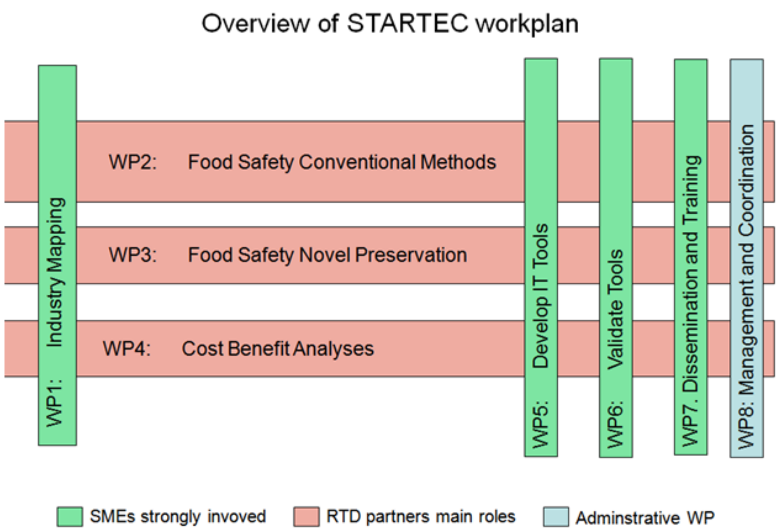
storage temperature, apply different preserving methods, using different ingredients, and so on. A prototype of the tool as tested and validated by the food providers and other experts participating in the project.

The scientific and technical objectives of STARTEC *(as stated in the DoW):*

1. To assess the supply chains, food production processes, and food safety and quality management systems in target food companies, who currently manufacture raw and heat treated ready-to-eat and convenience products prepared from meat, seafood, dairy and vegetables.
2. To evaluate and model the growth and survival of pathogens, toxin production and degradation, and quality changes including organoleptical and nutrition loss in food model systems where different ingredients are combined. The evaluation will be based on current scientific data and new experiments.
3. To assess the effectiveness of conventional and new preservation techniques as well as intelligent packing and time-temperature monitoring technologies on food quality and safety, and investigate whether any of these approaches can be used as an extra "safety switch", "quality switch" or "nutrition switch" when enhanced products are needed.
4. To carry out cost-benefit analyses related to the production of standard and enhanced ready-to-eat and convenience foods.
5. To develop a user friendly IT tool (to prototype level) and guidelines for rapid food safety risk assessment and decision support in a cost/benefit perspective.
6. To validate tools and strategies for improvement of the quality and safety of standard and enhanced ready-to-eat and convenient foods.
7. To disseminate the results to key stakeholders, including food business operators, food authorities and food policy makers.

The project was organised in 8 work-packages, as shown below. Activities in the different phases were carried out in parallel, to achieve the objectives in a three year timeframe. This required an integrated approach and a high level of collaboration between partners to ensure that the activities would be useful for the partners who were going to use the results later, and vice versa, the users of the results had be involved in planning of the activities.



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4.1.3. Main S&T Results and Foregrounds

Industry mapping [WP1]

The overall aim of WP1, industry mapping, was to select the parameters and products to study in the project, develop downscaled systems for production of selected products for use in laboratory experiments in studies of conventional and novel technologies as well as to map data and experience from industry with relevance for the project context.

All four contractual Deliverables were prepared and submitted in accordance with Annex 1.

Selection of products and parameters, initial desires for the STARTEC tool:
Before selection of products and parameters, the partners discussed and decided the scope and approach of the STARTEC tool. A draft based on categorisation of ingredients, processes and storage conditions was presented at the kick off meeting. The response from the industry partners was that the tool needed to focus on real challenges, and that decision support is needed where there is uncertainty. Use of categories was considered useful, and the essential step would then be to categorize products correctly in 'red, yellow and green areas', corresponding to 'unacceptable, marginal and good' for various parameters describing food safety, quality and costs. The categories should preferably be adapted to intended consumer groups, including vulnerable consumers and customers demanding a long shelf life. Further, it was desired that the tool should provide corrective actions to move from red and yellow to green category. It was pointed out that the corrective actions should not be theoretical ones, but possible for the industry to apply. It was initially decided to focus on two kinds of products: full meal deli salads and ready-to-heat products for microwave heating. In addition, lasagne was included for mapping purposes to compare practices between companies, as all the three FBOs in STARTEC produce lasagne with similar compositions.
At the EC midterm review, it was recommended to select one product for development of the decision support IT tool. We chose pasta salad and three scenarios:

- Two formulations of salads, one with cooked vegetables and one with raw. The two salads are produced commercially by the project partners Matbørsen and Forno Romagnolo, and lab scale production systems could easily be established.
- Two packing atmospheres: modified atmosphere (CO_2 and N_2) and air.
- Normal and abuse storage temperature conditions, 4 and 12 °C, respectively.

The selection was done based on criteria like high relevance for both industry partners and researchers, relevance for vulnerable consumers, possibility to include cost, nutrition and quality studies, possibility to mimic industry conditions in the lab and, the opposite, it should be possible validate results from wet lab with products produced in industrial scale.

Dissemination: The activity was basically an internal activity with the purpose to give the background and a framework for the studies in the lab and for development of the IT tool. The selection of the approach, i.e. a tool based on categories and realistic corrective actions has however been disseminated, for example included in presentations at conferences and in communication with food authorities.

Mapping activities in "walk and talk" visits – multidisciplinary dilemmas and complexity management:

Production of mixed ready-to-(h)eat products is by nature complex. In order to learn about industrial food production and how the industry manages the complexity, researchers from the STARTEC research partners visited the food producers in "walk and talk visits" along the process lines. Process steps and formulations which could involve food safety risks were noted and analytical data from the companies were used to assess the risk areas.

Some individual products consisted of as many as 50 ingredients with different logistic chains. Full meal products can be divided in at least three groups: 1) the "single component products" where the final heat treatment is carried out together (e.g. lasagne), 2) the "several component" products where one or more ingredient is added to the product without any heat treatment (e.g. a deli salads where cold smoked salmon is one of the ingredients) and 3) the "sequence heat treated products" where all ingredients are heated but some only in the last few seconds (e.g. paella or fish soup with scampi). For the latter two processes model schemes, critical control points in the safe branches of the processes are of limited value if an "unsafe ingredient" is introduced without any treatment to remove or reduce the risk. If an ingredient could be heated or the food safety risk cannot be managed in other ways without loss of quality, alternatives like formulation of the product without the ingredient which is considered as high risk, and recommendations to the customers to supply the ingredient themselves shortly before serving were suggested.

Limited physical space and the need to maximize use of resources was a challenge. With many different products within one facility there was a risk of unintended mixing between products and raw material, crossing of production lines, and so on. To ensure food quality, safety and nutrition in a cost effective way as possible, the industry minimized the likelihood of mistakes. All the companies stated that clear structures, planning of standardized products and procedures was better than ad hoc decisions when mistakes occur. Furthermore, a small group of people in-house were selected, trained and empowered to make informed decisions about food safety and quality. Another approach was to standardize and simplify the in-house production. Ready-made pre-mixes of ingredients were used to reduce the risk of incorrect composition. The drawback of out-sourcing was less overview of one's own production and the company having to rely on the supplier to ensure safe ingredients. For instance, if precooked and/or frozen ingredients were bought pre-prepared, and added to the products after thawing or only a short heat treatment, it saved time and need of staff. Similarly, cooling processes are slow but can be accelerated by adding cold water, ice, frozen ingredients or by using a heat exchanger. However, these options introduced a risk of recontamination, which was also seen in the analytical data carried out in the internal control systems: product with pre-prepared ingredients and accelerated chilling had generally higher total counts of bacteria.

Cheaper products could be produced by replacing the most expensive ingredient with a different ingredient (e.g. king crab with crab sticks) or by omitting the ingredient completely. The new composition was then a new product with its own specification. Exchange of an expensive meat ingredient with a cheaper ingredient on ad hoc basis was normally not an option, both because the specification would normally not allow it, and because ad hoc changes introduced an unacceptable high risk of mistakes.

In general, it was seen that the food industry has to manage multidisciplinary dilemmas:

- The option to increase the production capacity by using preprocessed ingredients provided from subcontractors or others versus the need of in-house food safety control of the products.

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- The need for different products within a category versus the increased risk of mistakes by more differentiated production and inherent complexities.
- Rapid cooling versus the risk of recontamination, i.e. the risk of overcooking in some parts and survival of microbes including pathogens in other parts.

Dissemination: The observations in the mapping activities were used to establish test systems for laboratory studies which have been disseminated to industry and the scientific community. In addition, the dilemmas and how the industry deals with the complexity have been disseminated in workshops with industry, the scientific community and to food authorities. Norwegian food authorities have included this in their training programs for auditors.

Audit campaign among producers of ready-to-eat products by Norway food authorities:
STARTEC was asked to contribute in planning and training of an audit campaign among suppliers of ready-to-eat foods carried out by Norwegian Food Authorities. 452 producers and suppliers of ready-to-eat foods, including industry and institution kitchens, were visited by auditors from the Norwegian food authorities. Most food producers (80%) had deviations. Of the 127 institution kitchens audited, most of them serving food to vulnerable consumers, 94 % had deviations, some of them serious like missing HACCP plans and lack of awareness of food safety. For the companies, most deviations were not critical, but in some cases there were strong disagreements between food producers and food authorities. Typically, the disagreements were related to sampling and risk assessment of products. Some key topics were:

- what an acceptable corrective action in case of a deviation was
- if a product can have a longer shelf life than the time it takes for *Listeria* to grow 2 log units
- the relevance of sampling, in particular product samples versus production environment samples.

Assessments on these topics were also pointed out as challenging in the mapping activities in and in discussions with external companies, indicating that the observations in the industry mapping seem representative and useful as a basis for development of decision support tools for industry.

Survey of domestic-scale microwave ovens
Initial laboratory studies of ready-to-heat products inoculated with *Listeria monocytogenes* indicated microwave heating was not sufficient to eliminate or sufficiently reduce the level of *Listeria* to ensure the food safety. Participants in the study were given sample products, an IR thermometer for measuring temperatures at various places in the products, and a questionnaire about which microwave oven they had, the heating procedure, etc. They were asked to heat the products as they normally do, and measure the temperature. It was found that even the most modern or advanced microwave ovens did not lead to sufficiently high and/or even temperature in the products, even when the products were heated according to the instructions on the food product label. In response to this, the food industry partners in STARTEC acted immediately and adapted the heating instructions on their product labels for consumers.

Dissemination: The results have been disseminated to industry and food authorities in workshops. Despite the relevance, the observations were not followed up in with more extensive studies within STARTEC, as studies of deli salads for the IT tool had to be prioritised after the midterm review.

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Coordinator: Norwegian Veterinary Institute, Oslo, Norway.

Experiments and analyses carried out by food industry partners in STARTEC:
All companies in STARTEC have willingly shared data from their internal control with the rest of the team, and carried out experiments in their facilities particularly dedicated to STARTEC. Some of the outcomes were:

- The sampling frequency of each product varied largely between companies. However, the results were basically the same for all companies. Pathogens were very rarely found, hygienic indicators above the internal limit were occasionally found, but from a practical point of view, high total counts was the only parameter leading to products in the "sufficient" and "not acceptable" categories instead of the "good" category.
- All companies used limit values for single samples for their decision support, either for detecting non-complying lots or analyses of trends. All companies had set limit values for total counts, hygienic indicators being either *E. coli*, coliforms, enterobacteriacea, other groups of bacteria which may contain pathogens ("foreign counts" which are total counts minus lactic acid bacteria), and specific pathogens. The companies had set significantly lower limit values for pathogens than what is specified according to the legislation.
- None of the companies used models for growth of pathogens in their internal control system.
- The pH in deli salads was normally in the range from 4 to 6. Salads with acidic sauces (mayo, dairy products, lemon and vinegar, alone or in combinations) and vegetables but no meat was likely to have pH in the lower region, while similar salads with added egg, meat and shellfish were likely to be in the higher region. This was due to that vegetables normally have a low buffer capacity, while protein rich ingredients have a higher buffer capacity and as well a higher pH. These observations indicated that the product formulation as well as the initial pH can be used to assess growth potentials and categorise products, even without analyses.
- The companies carried out storage trials of some of their products and measured total counts. The levels increased in most products during storage. In products with cooked meat, the increase during two weeks of storage was up to 3 log units during chilled storage. In some products, the levels remained low. A high growth potential of total counts and "foreign" counts indicated that other (pathogen) bacteria may grow in the products as well.
- Raw vegetables were sources for high total bacterial counts. Use of acetic acid in the washing water of vegetables was tested in specific STARTEC experiments in one of the companies, and found not suited for reducing the total counts.
- The temperatures during chilled storage and distribution of products varies between countries but even more between shops. Storage at ideal chilled conditions cannot be assumed.

Dissemination: Experience data from industry is sensitive information and should not be disseminated unless anonymized. Several of the observations have however been included as a basis for development of the tool and laboratory experiments, and have been presented at workshops with the permission of our participating food companies. Publication of such data in scientific journals could be possible in the future.

The impact of industry mapping in STARTEC beyond project internal activities:
The mapping studies in STARTEC showed a high complexity and identified multidisciplinary dilemmas in industrial production of advanced ready-to-eat foods which can compromise the food safety or at least the safety margins. The complexity was expected, but the practices used to

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increase production capacity, like use of prepared/pre-cut ingredients from suppliers without any risk-eliminating treatment in-house, accelerated cooling processes, and more branched and overlapping production chains between products, were higher than expected. Further, the corrective actions normally suggested by risk assessors and food authorities were not always possible to use for the industry. For instance, it is not an option to cook a product for four minutes longer, shorten the shelf life a week, or similar, as the product may not be in the market if these changes are done. During the review process and in discussion with others, it became clear that a main output of the mapping activity actually was *how the industry deals with the complexity* in their organisations on a daily and longer term view. This kind of knowledge is important for how decision support tools should be developed. In this period, we have had discussions with external experts in modelling and tool building. One stated that '*I am sceptical about the likelihood of success of a tool. It is hard to develop such tools and even harder to make someone use them'.* This was from an advisor with expertise in development of similar tools. He also stated that '*It sounds as you know what the industry need and which corrective actions they can do. This is knowledge I and many others need'.* Based on this, and the mapping studies in industry, we consider that a key output of STARTEC is a well-elaborated user specification for a food safety decision support system.

Food quality and safety – Conventional production [WP2]

The WP2 main objectives were:

1. to evaluate and model how defined food safety and quality parameters change in food model systems when different ingredients are combined in raw and heat treated RTE and convenience products (D2.1), during their distribution and storage, up to the consumption (D2.2);
2. to define performance objectives (POs) for target biological hazards in ingredients going through a specific production process (D2.4) with the aim to support the achievement of food safety objectives and microbial criteria as established in the EU legislation on RTE foods;
3. to investigate the pathogenicity changes in target microbiological hazards in relation to different production technologies (D2.3);
4. to write practical guidelines for industries on how to manage safety and quality of RTE products (D2.5).

The activities performed allowed completion of all Deliverables scheduled for WP2 in the DoW. The main achievements related to each objective are described below.

Evaluation and modelling how defined food safety and quality parameters change in food model systems when different ingredients are combined in raw and heat treated RTE and convenience products, during their distribution and storage, up to the consumption:

The results obtained in RTE products in relation to the impact of mixing different ingredients on the safety and quality of the RTE products showed that fresh vegetables represent the main source of foodborne pathogens and their appropriate washing is a key step to increase product safety. Consumption of fresh produce and addition of fresh produce in RTE products has increased over the past two decades. Since most fresh produce receives minimal processing and is often eaten raw, pathogen contamination can represent serious risk. Further, cutting, slicing or peeling cause tissue damage which releases nutrients and facilitates growth of microorganisms. Microbial contamination can occur during any of the steps in the farm-to-consumer continuum (production,

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harvest, processing, wholesale storage, transportation or retailing and handling in the home) and this contamination can arise from environmental, animal or human sources. Understanding the reasons for the increasing contribution of contaminated produce to the overall burden of foodborne illness will shed light on measures likely to be most effective in reversing this trend.

Salmonella was never detected in the tested spelt salads and relative ingredients whereas *Bacillus cereus* and *Listeria monocytogenes* can occasionally contaminate the salads even if at very low concentrations. However, keeping modified atmosphere pack (MAP) during storage and decreasing the initial product pH, with the consequent growth of lactic acid bacteria, seem efficient to control the multiplication of those pathogens.

The supply chain variables impacted on both safety and quality of potato salads artificially inoculated with *L. monocytogenes* which was able to grow, survive, be partially or fully inactivated below the detection limits, depending on product formulations and storage temperatures. The level of pathogen went below the detection limits (i.e., 10 CFU/g) during storage at 4°C in formulations where preservatives (e.g. vinegar) were added. At abuse temperatures storage conditions *L. monocytogenes* was often eliminated in the presence of fermented dairy products due to an increase in the number of lactic acid bacteria coupled with a drop in pH. Non fermented dairy products, such as quark and cottage cheese, seem not to have the same preserving effect. This is interesting, because the two ingredients are often used by people on low fat diet, and are generally recommended for people who want to lose weight. We cannot tell whether the reduced preserving effect was due to low fat or less/other lactic acid bacteria than in sour cream but it is clear that trade-offs between healthy and safe food is not always straight forward. If the purpose is to produce a more healthy (low fat) product, and a product that can be stored without compromising the food safety, it seems to be a better option to replace parts of the fatty, fermented dairy products with non-fermented low fat versions, but not all. The impact of different ingredients on survival and growth of *S. aureus* was quite different because it did not survive and produce toxins in any potato salad formulated with whatever ingredient.

Potato salads prepared with freshly or pre-cooked potatoes showed an overall similar quality. Addition of chicken meat increased the pH with up to 0.5 units, and thereby enhanced survival and growth of *L. monocytogenes* compared to similar formulations without added chicken meat. Combinations of the presence of meat, less amount of sauce, slightly acidic pH (4.5 to 5) and abuse storage (12°C) created the worst scenario for the quality of most of the potato salads due to mould formation.

Growth of *S. enterica* in a salad consisting of fresh-cut Romaine lettuce mixed with non-produce ingredients exceeded that in lettuce alone at temperatures known to occur in distribution systems or during subsequent handling by consumers. Evidence derived from studies performed with a model system and in the mixed ingredient salad indicated that contact with cooked chicken meat stimulated rapid growth at the surface of contaminated lettuce leaves. These findings demonstrate the critical importance of strict temperature control during the manufacture, distribution, handling and storage of salads formulated with ingredients that could stimulate the growth of pathogens such as *S. enterica.*

All of the tested ready to heat products including the meatball dinner, fish soup, chicken stew and paella support the growth of *L. monocytogenes* during storage at 4°C within the specified shelf-life time. In some products the presence of modified atmosphere prolonged the lag phase duration, reduced the growth rate as well as the maximum pathogen density compared to samples packed in non-MAP condition. In addition, MAP plays a significant role in preserving the quality of some

ingredients. Microwave treatment recommended to heat the product was not efficacious to eliminate *L. monocytogenes* completely. On the contrary, the heat treatment in standard cooking oven reduced/eliminated *L. monocytogenes* below the detection limit.
During storage growth of Lactic Acid Bacteria occurred in almost all products. Their increased number was associated with drop of pH and often blowing of packages especially in the products held at +14°C. The presence of Enterobacteriaceae was common in presence of fresh vegetables (celery, cherry tomato, rocket salad). Their number did not decline and in tortellini pasticciati increase during the shelf life. Number of Listeria spp. was always below or close to the minimum quantification level (10 cfu/g) and the number remained low during shelf life. *L. monocytogenes* was detected in two lots of ravioli salad. The prevalence of positive samples increased during shelf life but number was below quantifiable level.
In the second half of the project, **pasta salads** were studied extensively in order to build models to be inserted in the IT tool.
The Baranyi no-lag with m=1 and Rosso no-lag seem to be equally a good choice modelling the data sets collected testing pasta salads challenged with *L. monocytogenes.* The Baranyi model offers the possibility of increasing the degrees of freedom (DFs) whereas the Rosso model can easily include the lag phase just adding one DF. A small number of DF is better when the data points are not a lot to stabilize the fits, then Rosso model is maybe more suitable in order to include the lag phase. Regarding secondary models, the square root and the gamma models described well some datasets, but not all. For the UNIBO datasets, data at 4°C showed a large variability and it was not possible to estimate the beginning of the stationary phase, i.e. the maximum levels of L. monocytogenes. This turns out in a lower value of μmax compatible with the gamma model description. For the NVI data sets, taking into account the pH and the temperature, μmax at 4°C is underestimated, while that at 12°C is overestimated. Reasons for the deviations were found during the validation studies, and the models predicted the growth correctly within the error margins.

On the nutritional side, the pasta salads with raw pepper had ascorbic acid depletion after 12 days of storage much lower (around 27%) than the salads with cooked bell pepper (around 45%). The only exception was in the salads with cooked bell pepper, packaged under MAP and stored at 4ºC, which did maintain their ascorbic acid content during the 12 days of storage period. Reducing the time in the washing procedure, the use of steam cooking, and the cut of larger pieces of vegetables are some suggestions that can minimise the vitamin loss during the processing of RTE salads. The use of MAP has been proven to be effective against vitamin degradation, so it should be used when appropriate. Control of the refrigeration temperature can also help in the preservation of vitamin content.

Dissemination: the results described have been included in a paper published in Journal of Food Protection, in a paper submitted to International Journal of Food Microbiology, in posters presented at International Conferences, in oral presentations presented for scientific events and wider public and in the organization of workshops. More papers are in preparation.

Definition of performance objectives (POs) for target biological hazards in ingredients going through a specific production process with the aim to support the achievement of food safety objectives and microbial criteria as established in the EU legislation on RTE foods:
The results collected in the project show the approach to derive Performance Objectives (PO) for *Bacillus cereus* (BC) and *Listeria monocytogenes* (LM) in selected ingredients to be added in RTE mixed spelt salads, packaged under air or modified atmosphere, with a shelf life of 12 days.

The research leading to these results has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under **grant agreement n°**289262.

According to the microbiological results collected in nine different lots of ingredients and final product, the POs for BC were calculated for spelt and cheese, whereas those for LM in cheese and celery. The sampling plans to reject the lots non-compliant with the derived POs are calculated, setting appropriate sensitivity tests. To derive the POs enumeration results and censored data are considered. Moreover, the most probable distribution of censored data is determined and Monte Carlo simulations performed to assess the uncertainty. The PO values to provide to the RTE producers to meet a Food Safety Objective (FSO) for *BC* of 4 Log cfu/g in spelt salads stored refrigerated under air or MAP for 12 days correspond for spelt to -0.64 and 0.22 Log cfu/g, respectively. For cheese, to be added in the same product stored under air or MAP, the PO values are -2.22 and -1.36 Log cfu/g, respectively. In order to verity the compliance to the POs calculated for spelt, *BC* should be quantified in a number of samples ranging between 9 to 18 using a microbiological method able to enumerate between 2 cfu/10g and 3 cfu/g. To verify the compliance to the POs derived for cheese *BC* should be enumerated in 9 to 20 samples using a microbiological method able to quantify between 4 cfu/kg and 9 cfu/100g.
The PO values to provide to the RTE producers to meet a Food Safety Objective (FSO) for LM of 2 Log cfu/g in spelt salads stored refrigerated under air or MAP for 12 days correspond for celery to -4.18 and -2.71 Log cfu/g, respectively. For cheese, to be added in the same product stored under air or MAP, the PO values are -3.43 and -1.96 Log cfu/g, respectively. In order to verity the compliance to the POs calculated for celery, LM should be quantified in a number of samples ranging between 9 to 20 using a microbiological method able to enumerate between 2 cfu/10kg and 1 cfu/100g. To verify the compliance to the POs derived for cheese LM should be enumerated in 7 to 19 samples using a microbiological method able to quantify between 1 cfu/10kg and 3 cfu/kg. The approach presented in this study can be easily adapted to different FSOs and changing assumptions. The use of spelt and cheese compliant with the suggested POs might significantly reduce the incidence of foodborne intoxications and infections due to BC and LM and the proportion of food recalls, causing huge economic losses to food companies commercializing RTE products.

According to the EU legislation food producers have to prove either absence of LM in the product, or that the level will not exceed 100 cfu/g at any time during the shelf life assuming that the product is contaminated. Therefore, a further objective of the activities developed in the project was to estimate the growth potentials of LM in pasta salads using the official guidelines and, based on these, indicate how the demands in the legislation could be fulfilled. The water activity and changes in pH and lactic acid bacteria levels in pasta salads during storage were similar for Norwegian and Italian salads. The initial pH dropped from 6.0, to 5.7 and 5.2 at 4°C and 12°C, respectively. The level of lactic acid bacteria in the salads exceeded the level which inhibits growth of LM after approximately a week of storage. LM grew in the products, but more rapidly during the first week of storage than later. Low temperature and packing in modified atmosphere both lead to less growth of LM than storage in air and at abuse temperature (12°C). Initial levels of LM were estimated to avoid that the legal limit in the legislation was exceeded by the end of storage. In case of air packed pasta salad, Listeria needs to be absent at the day of production to avoid levels above 100 cfu/g by the end of shelf life. If the salads are packed in MAP and stored at 4°C initial levels 1-5 cfu/g may lead to levels above 100 cfu/g if the storage time is 12 days or longer. If salads in modified atmosphere are stored at 12 °C for some periods, initial LM levels of approximately 2 cfu/10 gram can lead to higher than 100 cfu/g in the product during shelf life. The initial limit values combined with the packing, storage temperature and shelf life can be considered as performance objectives for managing of the Listeria risk of the tested products. In addition, a list of possible corrective actions has been developed to improve the food safety of products with a high growth

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potential of LM. The list is based on studies carried out in WP1, 2, 3 and 4 in STARTEC, and was implemented in the IT tool as support information.

Dissemination: part of the results described has been included in a publication submitted to the International Journal of Food Microbiology. Another paper is in preparation.

Investigation of pathogenicity changes in target microbiological hazards in relation to different production technologies:

Mechanisms underlying how *L. monocytogenes* (LM) transit from saprophytic lifestyle to a pathogenic lifestyle are not fully understood. Molecular methods have been used to comprehend factors that promote virulence traits of LM. *Staphylococcus aureus* (SA) is considered as a pathogen in typical "catering food", like deli salads and food stored for several hours between 15 and 60 °C. The understanding of SA toxins is that they are extremely stable, but more use of advanced typing methods during the last years has opened for speculations whether contamination shortly before serving is more likely to cause illness than contamination in early production steps.

The aims of the studies performed were (1) to show how pathogenicity of LM changes in RTE products packaged using different technologies and stored at different temperatures; (2) to investigate the stability of SA toxins during storage.

The influences of packaging conditions and abuse temperature storage on virulence gene expression of *L. monocytogenes* in pasta salads was initially planned to be investigated by using real time RT-PCR. Due to inherited methodological problems in mRNA extraction as well as purification from a food matrix, virulence gene expression analysis was not preformed. Instead, the impact of different product formulations, packaging atmospheres and storage temperatures on the survival of specific *L. monocytogenes* strains was assessed quantifying changes in specific strain types genotyped using PFGE. Moreover, the stability of SA toxins was assessed in Italian and Norwegian pasta salads stored at different temperatures and packed under MAP and air.

The results collected showed changes in the percentages of LM pulsotypes detected at the end of the shelf life in pasta salads formulated using the same or different ingredients, packaged under ordinary as well as modified atmosphere and stored at appropriate and abuse temperature. The same result was also obtained testing single ingredient like cheese and speck (ham). Since the LM strains investigated in the research where those experimentally inoculated in the products and in the ingredients and they were all adapted in the same way before the challenge, these results show that there is an effect of storage temperature, packaging atmosphere and interaction between ingredients on the possibility of specific strain types to survive in RTE products until the end of the shelf life.

Staphylococcus toxins. The objective of the study was to investigate the stability of toxins in Italian and Norwegian pasta salad stored at different temperatures and packed. Two experiments were carried out, using SEA as test toxin. Detection of SEA was done by Ridascreen SET Total kit, which is a sandwich-type enzyme immunoassay (ELISA) for detecting the combined staphylococcus enterotoxins types SEA to SEE. The first and the two last experiments give partly contradictory results in terms of initial reduction of toxins. During storage, however, all the three experiments indicate stable levels of toxins are found in salads from day 2 independent of packing method, composition and storage temperature. The experiments need to be repeated several times to draw a conclusion regarding initial reduction of SE levels, but within the frame of STARTEC, we choose the worst case scenario as the best one for the tool: no degradation of Staphylococcus toxins during storage.

The research leading to these results has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under **grant agreement n°**289262.

Dissemination: part of the results described has been included in a paper published in Canadian Journal of Microbiology, in posters presented at International Conferences, and in oral presentations to scientific event.

Practical guidelines for industries on how to manage safety and quality of RTE products:
The main results of STARTEC project have been translated in key recommendations to the industry presented as guidelines. In fact, the research behind each recommendation has been detailed. The recommendations provided are the following:

- Approval of the quality and safety of ingredients or products from **suppliers** should be a fundamental part of the food safety management system of food producers. Quality and safety standards achieved by suppliers have a direct effect on contamination levels of ingredients, including those that can hold latent biological hazards and that are not subsequently reduced or eliminated using lethal processing treatments.
- The **shelf life** of RTE products should be established on a case by case basis, taking into account **product composition** (for example, presence of raw ingredients like vegetables and cheese), individual treatments applied to each specific ingredient (for example, thermal treatments, washing processes, cutting), and type of product packaging.
- Potato salad can be **formulated** to become safe, tasty and nutritious, even for vulnerable consumers. This can be obtained by applying sour cream or other dairy products with inhibiting lactic acid bacteria in the sauce, and apply enough sauce to ensure that the surface of all ingredients are covered. In full meal potato salads, meat and other ingredients which increases the pH or have a high growth potential of pathogen bacteria should not be included in the main product, but supplemented shortly before serving.
- There are multidisciplinary dilemmas and challenges associated with various **process steps** used in food production. Food safety risks can be reduced without compromising product quality and production costs if the **complexity in production** of advanced ready-to-(h)eat products and multidisciplinary dilemmas are taken into account. Challenges with branched process flow and use of preprocessed ingredients need to be included in the HACCP to ensure the food safety. The likelihood of mistakes leading to risk of foodborne illness can be reduced by adapting product formulations, process steps and staff training.
- The **Performance Objective** (PO) is a risk management concept we should became familiar with in the future. The PO calculated in the STARTEC project for *Bacillus cereus* in spelt to be added in a mixed spelt salad packaged under modified atmosphere (MAP) corresponds to 1 CFU/g. This concentration level decreases to 2 CFU/10 g if the spelt is added to salads packaged under air. In cheese the POs calculated when this ingredient is added in a spelt salad packaged under air or MAP are 6 cfu/kg and 4 cfu/100g, respectively. The use of spelt and cheese compliant with the calculated POs helps food industries to put on the market spelt salads in which *Bacillus cereus,* eventually present in the starting ingredients, will not reach a dangerous levels for public health at the end of the shelf life.
- Food products and conditions can be categorized using a traffic light system of red, yellow and green, corresponding to unacceptable, marginal/sufficient and good. Yellow and red categories indicate that a corrective action or special care has to be taken. Food safety categories can be set up based on the growth potential *of Listeria monocytogenes*. The categories can be customized for normal and vulnerable consumers or depending on the customers' demands. If the growth potential of *L. monocytogenes* is not known, categories can be indicated based on product formulation or indicator bacteria.
- The risk of *Listeria monocytogenes* can be managed by setting suitable performance

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objectives consisting of maximum initial levels of *Listeria* combined with intended storage conditions and intended use. For products with high growth potential of *Listeria*, additional corrective actions may be needed. Some options suitable for large scale production are given in this guideline.

Dissemination: the guidelines have been included in the tool and will be available in the project web site, and in oral presentations to scientific events.

Food safety and quality – Novel preservation [WP3]

The aims of WP3 were to evaluate how defined food safety and quality parameters change in food model systems which correspond to RTE and convenience products, when novel preservation technologies are applied. We aimed to investigate for which food combinations or food model systems novel processing techniques were useful based on which are most effective (in terms of quality, safety and cost).

The following novel technologies were identified and studied:

1. **High pressure processing (HPP)**. It can be used in liquid or solid foods of animal and plant origin, as well as in mixed RTE meals. During HPP treatment, the pressure is distributed instantly and uniformly throughout the food. It is proven to be effective against vegetative bacteria and results in good nutrient and colour retention compared to conventional treatments. It has increased applicability and established use of the equipment in the industry.
2. **Microwave processing**. It is a form of dielectric heating, which has numerous applications in the field of food processing (e.g. pasteurisation, sterilisation, thawing, tempering). Microwave heating has gained popularity in the food industry due to its ability to achieve high heating rates, reduction in cooking time, more uniform heating, safe handling and low maintenance.
3. **Antimicrobial packaging**. It is a form of active packaging utilised to extend the lag phase and restrain the growth rate of microorganisms in order to extend the shelf life and to maintain product quality and safety.
4. **Biopreservation**. This technique enhances food safety and stability using microorganisms such as lactic acid bacteria (LAB), yeasts, bacteriophages and/or their metabolites without altering the nutritional quality of raw materials and food products.
5. **Cold Plasma**. The application of non-thermal plasma for food decontamination is quite recent; however, this technology appears to be a valuable alternative to the washing procedures with chemicals for fresh fruits and vegetables and a promising tool for the products that cannot be sanitized with conventional means.
6. **Time Temperature Indicators (TTI)**. This type of packaging can provide evidence on the time-temperature history of the package throughout the whole distribution chain, and give indirect information on the characteristics of the food. The basic idea behind temperature-related food indicators is that generally the food deteriorates more rapidly at higher temperature, and thus maintaining correct storage temperatures ensures food safety.

Several experiments were conducted in order to evaluate these technologies alone or in combination with other technologies. Conventional preservation technologies were also employed as a control. In the majority of the studies reported in the literature, surface and volume active processing technologies are applied in raw or cooked single food products both in meat and meat products, such as chicken breast, burgers, sauces and vegetables. The selection of the specific food product types to be used in the project took into account the suitability of the products and the

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selected preservation technology, the practices in the food companies in the consortium, products representative of all companies and geographic locations with potential input from all RTE partners and, specific food products with composition as close as possible to the actual food products that the SMEs are using.

Dissemination: This extensive review has been accepted for publication in the *International Journal of Food Science and Technology*. It will be of importance to the research community but also to the industry as it provides a detailed guide on the suitability and efficiency of these technologies and facilitates their adoption.

Effect of High Pressure Processing on RTE/RTH lasagne:
The RTH lasagne is a common food product in all the involving SME's participating in STARTEC. Lasagne provided by a participating food company was used to carry out the experiments at QUB/AFBI. The product was already cooked and HPP was applied at different time and pressure levels. The application of HPP improved the shelf life of RTE lasagne by means of reducing the TVC and LAB counts, and *Pseudomonas spp*. complete inactivation. Even at abuse temperature storage, HPP extended products' shelf life by more than 30 days. Pressure level applied did not play a significant role in terms of shelf life but it did when pathogens were involved; the application of 600 MPa for 1 min killed and inactivated *L. monocytogenes* when storing lasagnes at 4^{o}C. This study also demonstrated the importance of keeping samples at refrigeration temperature; at abuse temperature of 8^{o}C an increase of both pathogens was observed. Regarding the sensory properties HPP did not significantly change the organoleptic characteristics of lasagne. In conclusion, the study suggested that HPP would be a suitable technology to apply post packaging to extend the shelf life and improve the microbiological safety of complicated multicomponent products such as lasagne.

Dissemination: These results will be published in scientific journal where the scientific community will benefit for future research.

Effect of novel continuous-flow microwave on tomato juice:
Fresh tomatoes were washed, cut and squeezed and a conventional or microwave treatment was applied to the juice. Novel microwave was successfully applied in tomato juice and did not change the physicochemical or the sensory characteristics of tomato juice. The juice treated with this novel technology was microbiologically safe and the antioxidant capacity of this product was not compromised. Since the product quality was the same as with the conventional treatment, the rest of the advantages of this new technology could be important for the RTE foods industry. Advantages of this new microwave technology include: continuous processing (not batch processing), maximum control over the heating process, and reduced processing costs.

Dissemination: The outcome of this research has been submitted for publication in the scientific journal *Food Chemistry*. Both industry and scientific communities could benefit from these results; the latter for new knowledge and future research and the industry as a new technology to be adopted.

Effect of HPP and antimicrobial packaging on cooked chicken breast:
Coriander Oil was selected as the most appropriate essential oil to use as active packaging. Films were coated with essential oil (or not), RTE chicken breasts were packaged with them and vacuum was performed for better contact between film and sample. Then, some of the samples were HPP

treated. Antimicrobial packaging reduced the safety risk from *Listeria monocytogenes*, and in conjunction with HPP enhanced its effectiveness by means of a synergistic effect. The use of both techniques, HPP and AP, could be a good option to minimize the safety risk and at the same time use milder processing conditions to retain product quality. However, temperature control has proved to be essential in reducing the risk of the pathogen. The active packaging with coriander essential oil did not introduce any considerable changes on the colour of the chicken breast meat. The level of lipid oxidation in the samples was very low in all treatments at both storage temperatures, showing that the pressure level used did not seem to result in high levels of lipid oxidation throughout storage.

Dissemination: These results have been submitted and accepted for publication in the *Innovative Food Science & Emerging Technologies* scientific journal. They will be of importance to the scientific community (specifically microbiologists) but also to the industry.

Effect of Bio-preservation on potato salads:
The lactic acid bacteria (LAB) naturally found in most of the tested dairy products may contribute for the safety and qualities of the potato salads especially at abuse storage temperatures. Care should be taken on formulations of the product, since some products became unsafe even if the LAB are high in number and the pH is low, possibly due to nonhomogenous distribution of LAB, different inhibiting effect of various LAB species, and local variations in pH. Vinegar in the sauce seems to control well the pathogens in the salads under the tested conditions. However, LAB may be preferred as “natural” and “health promoting” bio-preservative. Biopreservation using *W. viridescens* can inhibit the growth of moulds and *L. monocytogenes* in potato salads. The mix of this LAB and lactate-acetate did not inactivate completely *L. monocytogenes* when the RTE potato salad was stored at 12 ^{o}C. The use of bio-preservation alone or in conjunction with HPP exerted a synergistic effect in the reduction of *L. monocytogenes* in a low-pH and previously cold sterilised RTE product (potato salad). When the protective culture was used alone, its effect was even higher at abuse temperature (12 ^{o}C) than at 4 ^{o}C.

Dissemination: These results will be published in scientific journals in order to be accessible by the scientific community and facilitate future research. The industry will benefit as well as a new strategy to reduce the safety risk in ready-to-eat products is presented.

Effect of Cold Plasma as surface preservation technology:
Water supplemented with chlorine was more effective than water treated with cold plasma to reduce the load of spiked bacteria in cut celery. The lack of decontamination effect of water treated with cold plasma might be due to the decay over time of reactive molecules. According to this poor decontamination capacity of cold plasma on vegetables in water the subsequent scientific activities were focused differently. Firstly, evaluating the decontamination efficacy of cold plasma applied directly on radicchio and secondly, evaluating cold plasma washing as promising technology for the disinfection of vegetables washing water. Cold plasma applied directly on radicchio showed high decontamination efficacy. In particular the load of *L. monocytogenes* experimentally inoculated on the surface of radicchio leaves was reduced of approx. 4 log10 CFU/cm2. The load reduction was maintained during storage at 4°C for 4 days and no regrowth was registered. However, although no negative effects on quality parameters were observed immediately after the treatment, a fast deterioration of the quality of treated radicchio was registered during storage. A fast decrease of the quality index during storage was also observed on Italian pasta salad prepared using cold

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plasma treated radicchio. Cold plasma washing was efficient in reducing the initial loads of *L. monocytogenes* and *E. coli* experimentally contaminating radicchio leaves and the respective washing water. It represents a promising water disinfection technology alternative to chlorine in order to avoid cross-contamination and enhance fresh-cut product hygiene during storage.

Dissemination: These results will be published in scientific journals where the scientific community will benefit for future research.

Temperature-Time Indicators [TTI] in the evaluation of the secondary shelf life of salad dressings: Time Temperature Indicators (TTIs) are interesting tools implemented in RTE products where the secondary shelf life is important. With these devices, consumers could be able to easily detect the remaining secondary shelf life of the product during storage. TTI should be accurately calibrated against sensory and/or microbial characteristics and their indication should be of informative nature. The nature of the product and the matrix play an important role (e.g. low pH products do not favour microbial growth). RTE products with low pH and an important amount of preservatives do not present a microbiological risk within the secondary shelf life provided by the manufacturer. Their physicochemical characteristics remained almost intact even during storage at temperature and time twice as recommended.

Dissemination: These results are of importance for the food industry in order to implement this technology. The outcome will be also presented to the scientific community in future congresses.

Cost Benefit Analyses for RTE products [WP4]

The overall aim of WP4 at the outset was to assess, using state of the art economic valuation techniques, the economic costs and benefits related to, and consumer demand for, the enhancements of quality and safety of Ready To Eat (RTE) and Ready to Heat (RTH) products. We worked closely with food-producing SMEs to obtain detailed information related to producing RTE and RTH goods under conventional and alternative (novel) production methods. During the second half of the project, we collected detailed information to ascertain the benefits to consumers from the enhancements arising under the STARTEC project on two products common to all SMEs partners (namely lasagne, RTH; and pasta salad, RTE). This information has been used to forecast the effects of these enhancements on the demand and market share of type of RTE and a type of RTH products. We also identified market segments and established the socio-demographic profiles of consumers who characterise these segments by using Latent class analysis. The survey on ready to heat lasagne and ready to eat pasta salad was administered in 6 countries (4 for pasta salad) within Europe; Republic of Ireland, Norway, France, Italy, Germany and Spain. This provided the opportunity to compare costs and benefit of producing RTE and RTH foods in different locations across Europe in one of the biggest study of this kind (7,850 respondents observed over 8 choices).

Baseline costs associated with production of RTE foods:
Results from the study on the costs associated with production of baseline and enhanced RTE/H products were collected in the report delivered in December 2013. We firstly notice that RTE/H meals have become increasingly popular in today's busy, consumer driven economy. Thus the need to improve such foods in terms of safety, production efficiency and nutrition for both healthy and vulnerable consumers is imperative. By nature RTE/H food processing is a complex process with

many interlinking and dependent tasks taking place. Potential dilemmas (as described by WP1) which the RTE/H industry may encounter have cost implications. Performance parameters for RTE/H producers are useful in helping SMEs to highlight areas where cost effectiveness can be improved. Regional differences are considered and based on the information provided by SME STARTEC partners costs per product are presented to demonstrate the cost structure of RTE foods and compare these across countries. Findings show that, whilst there are differences across countries, the cost structure is generally similar.
The analysis of the costs associated with producing Ready To Eat/Heat (RTE/H) products (following maps from WP1) took place during the second/fourth quarters of 2013 and resulted in the submission of D4.1 Report or publication on SME costs associated with production of baseline and enhanced RTE and/or RTH products. The data available on the topic from the SMEs were gathered from the partners and additional data were acquired from web searches and industrial contacts. For all other missing data we worked on assumptions. Those data have been then integrated in the IT tool. Following the strategy of the team to focus on particular products, we included only those specific costs in the IT tool, using the available maps.

We suggest that a further development of the IT tool should allow the user to include all the costs of the company relevant to the analysis included in the tool at a profile level (possibly these should be imported from the software used by the company to store data on costs.

Dissemination: The report on costs (D4.1) was delivered at the end of December 2013. The results have been communicated at conferences.

Costs and benefits associated with alternative RTE production methods:
For the deliverable D4.2) Report or publication on benefits of enhanced RTE products for regular and vulnerable consumers, it has been important to acquire information on public preferences towards different production methods and characteristics of RTE/H products. A questionnaire was developed during the fourth quarter of 2013 and administered in December 2013 – January 2014. Data were collected in 6 European countries (Republic of Ireland, Italy, Norway, Spain, Germany and France) on 2 different products, namely “ready to heat lasagne” and “ready to eat salad”. The final dataset comprises 7,850 respondents with 8 usable observations each. We were interested in studying the trade-offs that people were willing to make across different attributes of the products (included safety and traceability) and its cost. Models were estimated in order to understand the shares of different products in the different markets given possible scenarios of new developments. This represents the biggest effort, to our knowledge, in trying to understand consumers’ preferences for RTH/RTE food and in developments related to it in Europe.
Additionally to the work on costs for the production of RTE/H products, WP4 focussed on consumers’ preferences and willingness to trade-off different characteristics of the products (including safety and traceability) and their cost. The deliverable D4.3) Report or publication on CBA of changing production methods for enhanced RTE products was prepared considering additional analysis on the survey data and data on costs retrieved in the months after January 2014. The work on the report highlighted how difficult it was to understand the costs of new technologies applied in STARTEC, especially considering the salad.
Novel processing technologies are discussed in terms of their costs and cost effectiveness. The discussion demonstrates that there are factors prohibiting industry from fully benefiting from these novel technologies, mainly due to the high levels investment required and the need for training, research and testing at industry level. During the last 6 months of the project WP4 worked on

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getting a better and more detailed description of costs for HPP, MAP and changes in processes of production for pasta salad and included all results that were required in the IT tool. Most of data not included in the IT tool are available in the document associated with the deliverable.

We found that consumers in general strongly prefer to know that the meat/ingredients in the RTE meals they buy are national i.e. from that region, and this is reflected in high willingness to pay (WTP) values attached in our models to this feature. Furthermore, considering lasagne, consumers in all regions prefer to know that the meat in RTE lasagne is tested for meat authenticity (this could be a result of the recent European "horse meat scandal"). Whilst similarities between regions and products are evident there are differences particularly when comparing WTP across regions. Respondents in France show a higher WTP for a lasagne where the meat is national while in Spain the Test of authenticity was considered most valuable, at €4.32. Differences are discussed in more detail in the text of the related deliverable, and should be taken into account when developing products suitable for all consumers and to successfully target segments in the market.

Dissemination: These findings were disseminated in different venues during 2014 and will be submitted in the form of manuscripts to journals in 2015/2016. The report (D4.2) was submitted to the commission in February 2014 and related results were presented at major international conferences, namely: Assured, safe and traceable food (ASSET) Food Integrity and Traceability conference at Queen's University Belfast – 8th-10th April 2014. The conference was attended by 350 delegates from 30 different countries; UKCRC Public Health Research Centres of Excellence Conference, 19-20 June 2014, Leeds; Away day centre for excellence for Public health, Newcastle, County Down, 28 Nov 2014; Participation at the world congress of environmental economists. Istanbul July 2014; and at the 14th European Association of Agricultural Economists Congress: Agri-Food and Rural Innovations for Healthier Societies, in Ljubljana, Slovenia, August 26 – 29, 2014.

Data for the decision support tool:
We organised an internal task force to work on the contribution to the IT tool (D4.4) to improve the quality and quantity of the data collected. Dr Marco Boeri (QUB) also joined the task force organised by the consortium on modelling for the IT tool, defining the models for the costs and benefits. Costs for the products in analysis were collected from the partners and from other types of sources in case of more complicated information (such as the cost of electricity or the cost of natural gas). We also considered the Italian "studi di settore" to gather generic information on the average cost of production of different products. The contribution to the IT tool from WP4 continued until late December 2014.

Finally, the team of researchers at QUB working on the economic side of the project delivered a cost-benefit analysis of different technologies designed to enhance the production of RTE/H food and collaborated with the other partners in the project to include the structure of cost and benefit in the IT tool. For this we collated information relating to the costs associated with using alternative processing methods including High Pressure Processing (HPP) and ultra violet (UV) light or procedures as well as the benefits, in terms of attaining price premiums associated with enhanced RTE products. We identified a particular group of vulnerable consumers where significant differences are realised in latent segment models as consumers grow older. Results on market share are forecasted for up to six countries including France, Germany, Republic of Ireland, Italy and Spain. Whilst pasta salad and lasagne are the two products investigated in our analysis, results are transferable to other RTE/H products and to different countries.

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Dissemination: The results from WP4 were input to the final IT tool and other WPs in STARTEC, but we have also produced some stand-alone information relevant to SMEs and consumers, in terms of costs and benefits of enhanced RTE/H products. Those results are included in the deliverables and will be disseminated in scientific publications in the next few months.
All the information delivered, and the methodology used, can be used by companies to forecast the effects of enhancements in the production on the demand and market share of RTH products. To enable market differentiation for RTE and/or RTH products we have also estimated latent class models, establishing the socio-demographic profiles of consumers who characterise different segments of the demand for RTE and/or RTH products.
We expect to publish most of the results obtained from the survey and the analyses related to the above mentioned deliverables in scientific journals in 2015/2016, cooperating with international experts across Europe and, possibly, starting new ideas for future projects.

IT Tool developments [WP5]

The objective of WP5 was to develop a decision-making, planning and risk-assessment software tool, based on the results and models obtained in previous work packages of the project. The IT application in itself was the most important S&T outcome of WP5, as well as an essential part of the project. The tool puts together a big part of the knowledge generated in other WPs of the project, and serves as the interface between this knowledge and the interested SMEs. The aim of the STARTEC IT tool is to support producers of ready-to-eat food products in their strategic decisions. The tool supports decision makers to assess the impact of normal and exceptional circumstances, as well as helping in if they are developing new products or making changes to processes. Due to the high complexity of the products, it is far from trivial to foresee what effects a decision/change can have on the safety/quality/cost of the final product. Our goal is to support these companies by predicting such effects without having to prepare the product. The IT tool will not totally eliminate traditional food safety management techniques, experimentation or analyses, but it is expected to support decision-making and possibly lower the cost and time of new product development.

The goal of this work package was not to create a service or a product, but rather to build a prototype application and to demonstrate a proof of concept. This has been achieved. It has been demonstrated that the approach works, and that it would be possible to create a product or service to help the companies in the above mentioned decisions. The development was focused on novel topics, such as the simulation of different parameters of complex products, and the user interface to make this functionality available for a wide audience without extensive training. Less development effort was put in other aspects, such as data safety, data security or scalability. Although all these are important aspects, there are well-established solutions for these.

The Integrated STARTEC tool can be found in the following address: http://startec-tool.iris.cat.

The application was built according to the principles of the Model-View-Controller (MVC) approach. This is a generic approach which separates business logic from its representation, allowing software engineers to focus on the business logic while designers can take care of the visual representation. Python programming language was chosen as the basis for development.

The research leading to these results has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under **grant agreement n°**289262.

The user interface of the IT-tool is client-server based. The server side is responsible for the application logic, whereas the client side is responsible for displaying the results and entering requests. The main advantage of this approach is that browsers which support standard mark-up languages (such as HTML) can be used as clients, no need to work on client implementation. The system can be used on any platform with a suitable web browser without prior installation. Based on user feedback, we target standard web browsers to allow work in an office environment. However, the model-view-controller approach allows the optimisation of the content to other (e.g. hand-held) devices without changing the application logic.

Parts of the STARTEC tool

The application consists of several modules, each with a well-defined function. The inter-operation of these modules makes the IT-tool more than the sum of these modules.

Measurement database module: This module allows storing data measured at different points along the preparation process of the products. The functionality of this module goes beyond that of a spreadsheet, as it allows a) storing product flowcharts in a systematic way; b) associating each measured aliquot with a specific point in the flowchart; c) storing such information in a way which allows for systematic search with computers. Because of this, the database structure allows searches for measurement data with various criteria and the result of such searches enable selecting data for modelling purposes or can serve as input to the Simulation module.

Product database module: This module stores the information that is relevant to the products a company offers, such as formulation, specification sheets, legislations, photos, etc.

Simulation module: The simulation module can be considered as the engine of the tool, since this gives novel information to the users. The risk-assessment and decision-making subsystem of the IT-Tool follows the general open philosophy, by not enforcing any particular algorithm to use. The tool only provides the framework which may be filled with modelling and decision support logic. Therefore, microbiological and other calculations are stored in the database and are not written in the source code. The source code only ensures that logic entered by users may be read from the database and executed in the system.

Although the aim of the tool is to provide a higher level decision support, in the background there are models which predict the value of some well-defined parameters. The models provide the scientific background for the decision support. The customizable code is made up of the various models to calculate the different safety, quality, cost and nutrition parameters, as well as the classification logic which is used to determine whether these parameters are in an acceptable region or not. The model, in the context of the MVC framework, corresponds to the information which the user of the system is interested in. The model provides this information through a programming interface and not a user-interface. In contrast to many database driven web applications, where the model part is an internal representation and interpretation of the data in the database, in the case of the STARTEC application the model corresponds to the complete logic of the application. The information in this case is the result of the simulation. Since the model does not have a user interface, it is provided by the view. The controller's task is to translate between the model and the view. It pulls the information from the model and passes it on to the view, which decides how to present the information.
Primary and secondary models can be found in the tool:

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- Primary models describe the collected data by fitting them independently. They depend on several parameters that can be adjusted to fit the data. e.g. to describe a growth curve the most important parameters are the maximum growth rate, the concentration at which the growth stops, and the lag period, which is the time of adaptation of cells to the environment before the growth starts.
- Secondary models describe the dependence of the previously presented parameters on environmental factors, allowing prediction of scenarios not studied directly, such as a different temperature.

The models that comprise the simulation module can interact along two dimensions: 1) models for one parameter may be chained after one another, such that the output value of one treatment may serve as the input value to the next treatment; 2) between models of the same treatment. In general, models may use the output of other models as input.

The output of the models, however, may not be directly comprehensible for non-scientific decision makers. Therefore a second layer, a classification layer was introduced which categorizes model result into a red/amber/green type of traffic-light system. The classification system is also configurable by the user. After making changes in the flowchart, decision makers will be able to see if some parameters (or parameter groups, such as safety) are in the safe zone, require attention, or are unacceptable. In this way, the decision support logic summarizes the predicted values to make them comprehensible by non-scientific end users.

The targeted user group of the IT tool:
SME producers of ready-to-eat food, who produce complex products, whose safety, quality and associated costs are challenging to estimate based on the ingredients and the recipe. These SMEs, however, often lack the in-house expertise in the field of microbiological (and other) models needed for a customized, accurate prediction.

The STARTEC answer to this contradiction is to split the task in two:

1. The IT-tool (in the strict sense) provides a generic platform only,
2. whose database can be populated by experts/consultants hired by the food producer to create customized models for its product.

As a consequence, **two main use cases of the system have been foreseen**,

1. Reading simulated information, mainly performed by executive decision makers. This group expects the tool to give a higher level overview that will allow them to compare the effects of the different product formulations, treatment settings, etc.
2. Setup the system, mainly performed by researchers or administrators. This groups is expected to have a good understanding of the inner working of the models in order to select the appropriate model family based on literature or own research and calibrate the model parameters.

Dissemination: The tool can be accessed online via http://startec-tool.iris.cat.

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Coordinator: Norwegian Veterinary Institute, Oslo, Norway.

A tutorial of the tool can be accessed online via
https://drive.google.com/folderview?id=0B9kCkwj1FAyOOXJ6QlowbkRRVk0&usp=sharing

The tool has been presented in the following events during project duration:

1. Workshop for Food Business Operators as part of "Teknologisk matforum" in Norway in October 2014.
2. Pre-conference workshop at the 28th EFFoST conference in Uppsala (Sweden) in November 2014.

The Consortium has plans to further disseminate the tool in the following events:

1. A workshop at the International Association of Food Protection (IAFP) conference in Wales (April 2015), where several other tools will be presented.
2. A workshop at the 29th EFFOST 2015 conference in Athens (November 2015) together with other developers of tools for ready-to-eat foods.

Validation [WP6]

The overall objectives of the validation activities were originally focused on two areas. Firstly, on testing and validating the proper functionality and reliability of the STARTEC database and software in a real industrial environment. Second, on comparing the predictive and decision-making power of the tool with control samples obtained using conventional methods. As the project proceeded, it was found that user-friendliness and relevance of the tool and STARTEC concept for industry should also be included in the validation.

This experience from the validation activities enabled improvements of the software design for industrial implementation as well as the overall usability and efficacy of the software in a real-world scenario. Furthermore the added value of the STARTEC tool and guidelines compared to other tools were assessed by the team and external experts, and recommendation for the future as well as exploitation plan was made.

Technical assessment of the IT structure and user interface:
The IT structure and user interface were assessed by IT experts who had not participated in the development of the tool. Several meetings were arranged and a technical audit was carried out by IT experts from the coordinating organization NVI. Before the audit, the partner IRIS was asked to come up with specific documentation. The conclusion from the auditors was: The prototype IT tool has been developed by a skilled team using modern tools and practices. Despite the fact that there at the beginning of the project was no specification in technical terms as to what the tool should accomplish, look like or perform (as this was to be based on the early studies in the project, particularly the work of WP1) – they found the prototype able to be built further on. A technical backup system for the tool should be made.

Dissemination: The recommendations were taken into consideration in further development of the tool.

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Test of user-friendliness and relevance of the tool for industry users:
The user-friendliness, relevance and function of the tool were tested in an internal survey among STARTEC partners, external companies, external experts and in discussions at specific conferences. A restricted version of the tool, tutorials and a set of exercises were prepared and sent to internal partners, experts and external companies. The test persons were also asked to fill a web based questionnaire.

The prototype tool worked after the intentions. All participants in the survey could open and use the tool in their browser, and the exercises worked well. Both the internal and external companies found the user-interface attractive. From external companies the mean score was 4, with 5 as the theoretical max level. On user-friendliness the mean score was 3 from external companies and 3.64 in the internal survey. All respondents would recommend the tool to others, and most of them assumed it would be useful for their own company if adapted to their processes and products.

The response to the prototype tool at conferences and workshops has been positive. The approach using a simple categorization system was considered relevant and useful. Several people from industry, food authorities and consultants immediately showed interest to use the tool if further developed. Researchers and developers of similar tools were also positive, and saw the prototype as relevant for further collaboration. Even though the tool is a prototype only, it seems to have a great potential for use in industry and consultants.

The results from the internal survey, the external survey, feedback from our advisors and at conferences indicate that further development of the tool is needed, that the prototype is a good and relevant start on a tool with functions which are not yet in the market. Relatively high scores on user-friendliness, combined the attractiveness of the user interface and desires of simplifications and even better user-friendliness indicate that the tool has a potential.

Dissemination: the tutorials and exercises were further developed to a training platform for the enhanced IT tool. The feedback from the surveys and discussions were considered during development of the enhanced tool.

The validity of the primary and secondary models for Listeria growth was tested using industrially produced pasta salads:
The Baranyi no-lag model had earlier been found suitable for describing the growth of *L. monocytogenes* in pasta salads, and the Rosso model seemed promising as secondary model. In this context, secondary models mean models which can predict the growth at other conditions than those tested. In order to test the predictability of these models, new experiments were carried out using commercially produced pasta salads. The models had been developed based on experiments at 4 and 12 °C. In the validation experiments, the 6°C were included to test the predictability of the secondary model. The growth of *L. monocytogenes* was correctly predicted within the error margins at all temperatures and for both pasta salad formulations. The models in the tool do therefore have a sufficient “predictive power” to be reliable and useful.
It should be noted that some variations between batches and parallel samples were observed from approximately 2 weeks of storage. This imply that the models are well suited for predicting initial growth rates, but less good for prediction of maximum levels after long term storage. The results indicate that possible reasons for late variations were varying remaining oxygen after packing in modified atmosphere, different levels of lactic acid bacteria between batches and growth beyond

the surface in some ingredients indicating local conditions supporting growth at late storage. Challenges in prediction of maximum levels of *L. monocytogenes* are as expected. Correct prediction of maximum levels is considered as an important research topic within predictive modelling and food safety in general.

Dissemination: The results from the trials will be included in scientific publication about growth models of *L. monocytogenes* in pasta salad. The observations of the effect of local variations within and variation in maximum levels will be studied further in other projects.

Enhanced tool:
An improved version of the STARTEC IT tool has been developed in the validation period the feedback provided by end-user. The enhancements include hardware changes; software library updates; new and updated models; flowcharts and parameters in the database, parameter summary box; improved limits and simulation traffic lights display; overall report creation functionality; support tab, guidelines, information and documents.

Dissemination: The enhanced tool has been presented to the European reference laboratory for *L. monocytogenes* (ANSES), and will be presented at conferences in order to establish collaborations and further development.

Status and impact of the tool – recommendations for further development of the STARTEC concept:
To date, there have been no patent applications to any of the project results in STARTEC. The potential for further development is however considered as very high. An exploitation plan for the tool was prepared and agreed.

It is generally agreed that the STARTEC IT tool prototype is promising with its multi-disciplinarity, process/real food production approach and flexibility to add more foods, models and pop-up information. The STARTEC consortium considers the structure of the tool as conceptually correct even though it can be improved. The strongest point of the prototype tool is that it is flexible and can be adapted to: different types of food company in terms of products, processes, complexity of flow charts, etc.; any multidisciplinary aspect and model for any parameter, which can be inserted; customized categorization using a traffic light system which can be applied for normal and vulnerable consumers; use of a corrective action/support section, which can easily further developed; and new functionalities based on either the database, models or both.

The STARTEC tool is based on a robust database populated with comprehensive data from multiple experiments, plus modeling work and all of this is linked to a functional interface. Compared to other tools like PMM, ComBase and FSSP, the STARTEC prototype tool it may appear simple. This is as expected. The other tools have been developed for experts and risk assessors rather than for the industry. The objective of STARTEC has never been to develop a competitor to these tools, but to contribute to decision support in industry.

The judgment and recommendations from the external advisors regarding the STARTEC tool prototype were:

- The industry focus is good and represents a contribution to the area. Keep this, it might be needed to go to one specific company and develop it for them. And do this 2-3 times to get enough knowledge.
- The top down user interface is intuitive and useful. It looks nice. It is not common that a prototype look so close to something real.
- The traffic light system for categorization is good and represents a contribution to the area. More focus on corrective actions to obtain a safer/better/more nutritious/more profitable product is recommended (more of.., less of.., exchange A for B). Knowledge is not something that can always be put into equations – sometimes the industry know things that can be put in the system (e.g. pH below 3 no growth), such aspects can be included.
- The tools already in the public domain have been developed for risk assessment, not so much for industry. Links to other tools can be made: Code lists are available in the public domain – harmonization is possible and desired. Database re-structured/modularised. Separate models and formulas. Export/import options. Industry might want to have a backup in their system.
- It was good that the project started from an unbiased perspective. The answers became more creative than if the tool had been built based on an existing tool.
- A unique set of experimental data has been generated.
- A tool covering single products and similar products will be useful. The suitability and quality of data and models generated by others needs to be checked before they are included in the tool.
- The industry will have to know about the tool and how to use it. Think of promotion and user right management. Put it in a public domain so that others can contribute and comment (put a system in place).

The project partners developed a list of specific topics for development. Further development can follow three main routes:

- In collaboration with developers of other tools, with focus on improved relevance for industry. The user interface and the multi-disciplinarity of the STARTEC tool will be our contributions to other tools.
- Further development of the STARTEC IT tool prototype and guidelines within its own frame. Targeted functionalities can be developed by more interference between database, model and simulation layers. A list of possible functionalities has been prepared.
- Generation of relevant data and models to fill the knowledge gaps identified in STARTEC can be done independently, and be inserted in any tool later. New products, more pathogens, more technologies, single ingredients combined with mixing and building databases with historical data for trend analyses are only some of the options mentioned.

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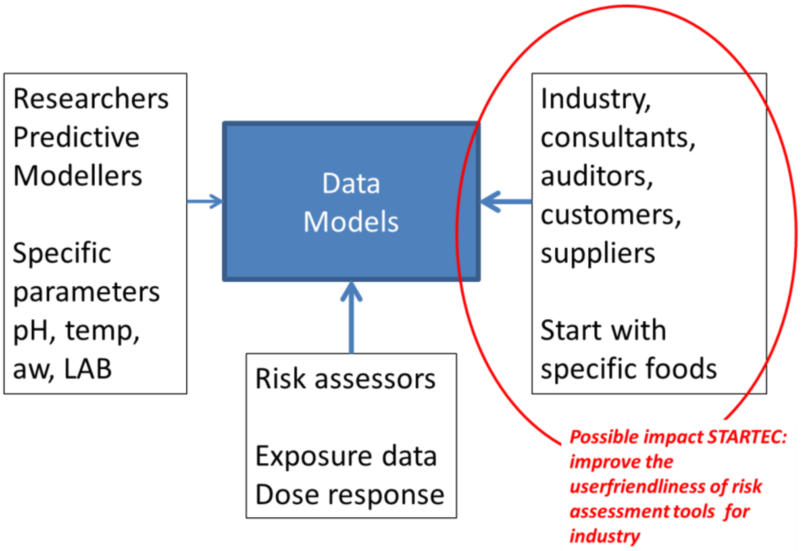

Figure 1: The contribution of the STARTEC IT prototype to other tools – improve the user friendliness by including the user-interface, real product and multi-disciplinarity aspects.

Dissemination: The results and future options will be discussed within the team and possible partners to explore the options for further development of the tool.

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4.1.4 Potential Impact, Main Dissemination Activities and Exploitation of Results.

4.1.4.1 Potential Impact of STARTEC

The idea for the STARTEC project was initiated by the EC Call Topic FP7-KBBE-2011-**2.4-01: Safety and quality of ready-to-eat foods.** The project concept and approach was developed based on the experience and knowledge of the project partners about the challenges in the food industry and the need for improvements in production of ready-to-eat and convenience products, especially for vulnerable consumers. Communication between participants in the project who are from research, academic, and industry backgrounds indicated that there were a realistic potential for improvement in the production of ready-to-eat and convenience products, if existing knowledge about the safety and quality of ingredients and new studies on the effects of mixing of ingredients were combined and made available in guidelines, or preferably in a user-friendly and IT tool. The research experience of partners in food safety, food quality, food technology, economics and cost benefit analysis, and IT tool development was essential to deliver the project outcomes, as was the input from food manufacturers involved directly in the project. Partners experience from international risk assessments, development of guidelines for risk analysis of *L. monocytogenes* in ready-to-eat products, international training and collaborations in food safety with research and industry partners provided critical inputs to the project work; these activities had shown that the challenges seen by the industry partners are, to a large extent, the same ones as those seen by European and international food authorities, but from another angle.

The **main expected impact of STARTEC** was that it would be easier for the industry to make safer and better products to different consumer groups in a more cost effective way by adapting the processes and ingredients they use today, or, if needed, by introducing new technologies if they are better than the existing ones. The prototype IT tool and the supplementary guidelines developed have been recognised as user friendly and relevant particularly for industry, and suitable for further development. For risk managers and food authorities, results from this project have made it easier to make indicative risk assessments, both for the industry, their suppliers and customers, the food authorities has used the results in their training program and planning of audit campaigns.

It was expected that suppliers of full meals would have to meet higher quality demands from their customers and carry more responsibility for nutrition and safety of their products compared to what suppliers of ingredients do. This is especially the case for suppliers of products intended served to vulnerable consumers having convenience and ready-to-eat foods as the dominating part of their diet. Both aspects have become real. New regulations for labelling of nutrition content will come in 2016, and the microbial criteria for *L. monocytogenes* in ready-to-eat foods are currently considered changed as the present ones have been difficult to implement. The STARTEC results and IT tool both contribute to easier implementation of these, as the studies have addressed exactly the topics currently being under consideration.

Relevance of the STARTEC outcomes for policy makers and the society at large:
Ready-to-eat and ready-to-heat foods are at least as relevant now as they were at the beginning of the project. An indication of their popularity is that the food producers involved in STARTEC have increased their production capacity between x2 and x5 during the project period, in line with general forecasts for increases in consumption of convenience foods. Ready-to-(h)eat products are commonly served to vulnerable consumers, as before. Regarding food safety, mixed products like sandwiches and deli salads, in particular *L. monocytogenes* in such products, are of particular

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interest and concern as they have been the source of foodborne outbreaks of listeriosis even at hospitals during the last few years (information provided by the European and national reference laboratories for *Listeria*).

The EU regulation 2073/2005 has three specific criteria for *L. monocytogenes* in ready-to-eat foods. The criteria are relatively new, but due to the challenge to implement them, it is currently considered to change two of them. To our knowledge, EU, DG SANTE, will send out a draft document about this to EU member states in April 2015.

The criteria in the legislation today are:

1.1 Absence of *L. monocytogenes* in products intended for medical purposes, which is defined as food served to consumers who are recommended a specific diet. An example is elderly people who are recommended to eat energy rich food as they normally eat so little that they not get enough energy and nutrition from the food.

1.2 For products which support growth of *L. monocytogenes*, the criterion is either absence in products before they are sent from the production facility, or that the FBOs can document that the Listeria level will not exceed 100 cfu/g at any time during the shelf life. Even though there are guidelines available for how such documentation can be given, the criterion have been challenging to implement, and some countries have chosen to accept absence of *Listeria* only.

1.3 For products which do not support growth of *L. monocytogenes*, the criterion is maximum 100 cfu/g, independently of when the sample is taken.

A number of questions have been raised about the criteria from food authorities and food business operators. Some of them are:

- Do products intended for medical purposes only include food served at hospitals/institutions only, or also other foods?
- If products which are considered as high risk for *Listeria* are needed to ensure sufficient energy and nutrition value for vulnerable consumers, what are best trade-off between risks and benefits?
- Challenge testing has been introduced to estimate the growth of Listeria in ready-to-eat foods, but they are not needed for products with shelf life shorter than 5 days. Sandwiches and other products which have given outbreaks have less than 5 days shelf life, but the source of have been traced back to contaminated ingredients with longer shelf life than 5 days. The relevance of the 5 days rule can be questioned.
- Challenge testing for single ingredients like cold smoked salmon or ham is relatively easy, but for mixed products, it is not clear how the studies should be carried out, for instance if the study should focus on the ingredient assumed to have the highest growth potential, if pH, water activity and other parameters needed for predictive modelling should be measured in an homogenised mixed product, or in each of the ingredients.

A significant part of the STARTEC project has addressed the microbial criteria and the challenges to implement them. The tool and guidelines, including categorisation of foods based on growth potentials of L. monocytogenes, have been developed for decision support particularly for such cases. We suggest that the STARTEC tool and guidelines can contribute to easier implementation of the microbial criteria and to make trade-offs between food safety, nutrition value and other multidisciplinary aspects possible, without compromising the safety of the food products. We therefore see a high possible impact of the STARTEC results both for policy makers and the society at *large. A significant part of the STARTEC project has addressed the microbial criteria and the challenges to implement them.*

Possible impact of STARTEC for European reference laboratory (EURL) for *L. monocytogenes:*
The STARTEC tool, guidelines and concept have been presented twice for EURL and all NRLs for Listeria in Europe, the second time after initiative from EURL. The group found the outcomes of STARTEC very relevant. EURL has already asked if the STARTEC tool can be used in new training programs about challenge testing, as an illustration and help to how challenge testing can be used to make good trade-offs between quality, nutrition value and costs can be made without compromising the food safety, a more clear connection between microbial criteria and challenge tests. EURL also considers the research activities in STARTEC as useful inputs for making challenge testing more meaningful. Both the food industry and food authorities have pointed out challenge tests are expensive to carry out, and that guidelines are needed to decide how different products have to be before new challenge studies are needed. In STARTEC, the growth patterns in pasta and potato salads have been determined, and moreover, it has been seen that change in one ingredient (e.g. slightly more preservatives) can overrule the growth pattern in the mixed products. Such studies can be used to indicate the impact of changing an ingredient, and further, provide information to show when new challenge tests are needed. Development of training and test programs in collaboration between EURL and STARTEC has started, and a high possible impact is seen for improvement of the food safety of ready-to-eat products within the framework of the legislation including microbial criteria.

Possible impact of STARTEC in the scientific community:
STARTEC has carried out a number of relevant studies for the scientific communities, and some are highlighted here:

- Studies of initial food quality and safety parameters in raw materials and products, as well as changes of products during storage. Several papers have been submitted, and more are in the pipeline.
- Easy ways to utilise product formulation to optimise food quality, safety and costs without use of additives or advanced technologies have been found. Some of the identified options will ensure the food safety and quality even by storage at abuse temperature conditions. Papers are in preparation.
- High pressure technology has been proven to be very promising, not only from a technical point of view, but also from a cost and feasibility point of view. The technology can easily be combined with other technologies, like bio-preservation and active packaging. The combinations are relevant, as high pressure treatment is effective for reduction of the levels of undesired bacteria, but cannot limit outgrowth of bacteria who has survived the treatment. Other technologies can however limit outgrowth. The combinations are of particular relevance for products where an extra “safety switch” and “long shelf life switch” is desired, e.g. for food to vulnerable consumers. Two papers are accepted for publication and more are in the pipeline.
- One of the largest studies on consumer preferences in a cost/benefit perspective has been carried out for two products in six countries. The study is unique, and will be published.
- The industry mapping activities revealed a lot of useful information which has been known both in industry and the scientific community, but often been ignored. By bringing the complexity and possible corrective actions which are useful to apply for the industry, the mapping activities provide the basis for research studies, particularly for applied research.

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Coordinator: Norwegian Veterinary Institute, Oslo, Norway.

STARTEC outcomes have been presented at several conferences and workshops. Four scientific publications have already been accepted, with four more submitted for publication. The number of scientific papers possible was determined by the duration of the project (three years) and the balance needed between research studies and the development of the multidisciplinary decision support tool; the IT tool was prioritised. Several more papers will are in preparation, which will further increase the impact of STARTEC in the scientific community.

Possible impact for industry:
The guidelines and decision support tool have been developed to make it easier for industry to make decisions, do trade-offs and keep an overview of complex production processes. The food companies within and outside of the STARTEC team have confirmed that the approach with real products and processes as well as simulation outputs with categorisation and the multidisciplinary approach is useful for them. They also pointed out that the tool needs to be further developed, and widely available in the future is it is to become really useful. It should be noted that our industry partners participated at all meetings and contributed actively in discussion and planning both in industry and research related topics. This reflects the interest high competence and dedication from the industry in the project. It is beyond doubt that the contributions from industry partners were very important for the development of the tool and guidelines, and also for the possible impact of the STARTEC results.

Possible impact of the decision support IT tool:
A prototype of an IT tool has been successfully developed and validated in the project.Tools can be made specific and be suited for a few functions, or generic and flexible so it can be adapted to many functions. In STARTEC, we chose to build a generic and flexible structure, implement pasta salads with a few scenarios and allow more products, models, and functions can be included at a later stage. It is generally agreed that the STARTEC IT tool prototype is promising with its multi-disciplinary approach, process/real food production approach and flexibility to add more foods, models and pop-up information. The prototype is useful for demonstration of the concept, but on the other hand, it needs to developed more to be implemented in industry.

The strongest point of the prototype tool is that it is flexible and can be adapted to
- the needs of any industry in terms of products, processes, complexity of flow charts, etc.
- any multidisciplinary aspect and model for any parameter can be inserted
- customized categorization using the traffic light system
- it can facilitate a corrective action/support section, which can easily be developed more
- new functionalities based on either the database, models or both.

The prototype tool has a large potential in itself, and in addition, elements of it may be useful to include in other tools. Many of the tools in the public domain have been developed based on models for various pathogenic agents studied in broth rather than in specific foods. Such tools are used by academia and expert risk assessors, but according to our knowledge, very little by industry. Based on our industry mapping studies and communication with industry inside and outside the STARTEC consortium, other tools appear as too abstract or complex, are not so well known among food industry companies, and that the industry bases their decisions on wider aspects than growth of pathogens in models systems.

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We assume that the user friendliness and relevance for industry of the established risk assessment tools can be increased if the user interface is more related to the industry challenges, real foods, processes and real options for corrective actions. The industry can use the same models and data as risk assessors, food authorities and researchers do. In this context, the STARTEC IT tool prototype can be used to develop the user interface of other tools to make them more user friendly for industry (see Figure 1). Addition of the multidisciplinary models and corrective actions which has been the intention in STARTEC will serve the same purpose.

Collaboration with developers of other tools, with focus on the user interface, is therefore a main route for utilization of STARTEC results (see Figure 2).

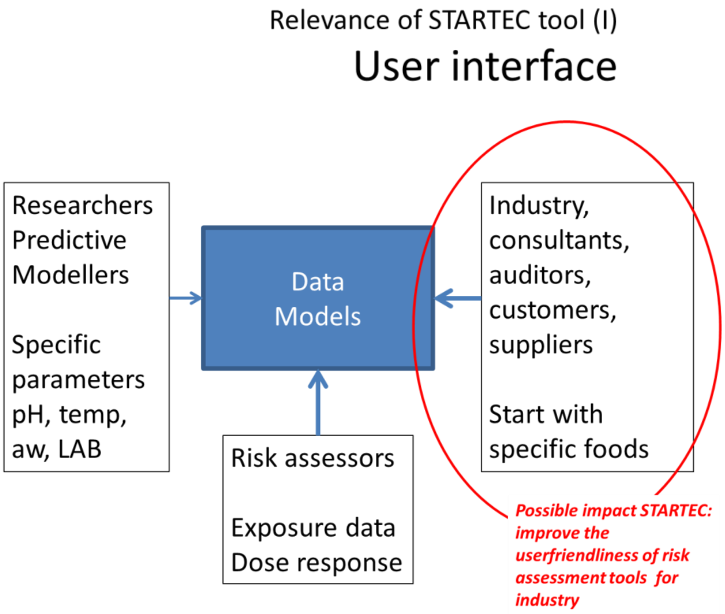

Figure 2. The contribution of the STARTEC IT prototype to other tools – improve the user friendliness by including the user-interface, real product and multi-disciplinarity aspects.

The STARTEC IT tool prototype and guidelines can also be developed within its own frame. The interference between database, model and simulation layers can be much more developed than they are in the prototype version. The more data there is in the database, the more useful it will be as a basis for company or trade-specific trend analyses of, for instance: analytical data in the internal control system; to compare prices and losses over time; to compare supplier's performance and deviations between distributors, and so on. More foods and processes can be included and the option to make multidisciplinary tradeoffs can be developed more by implementing more models (see Figure 3). This route was actually what we set out for when STARTEC was planned. From our point of view, the concept has been demonstrated positively for the products and scenarios studied. We see the benefit of developing the tool for more processes and foods. This kind of tool may also be useful for auditors, consultants, food authorities, in training as well as in the industry.

The research leading to these results has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under **grant agreement n°**289262.
Coordinator: Norwegian Veterinary Institute, Oslo, Norway.

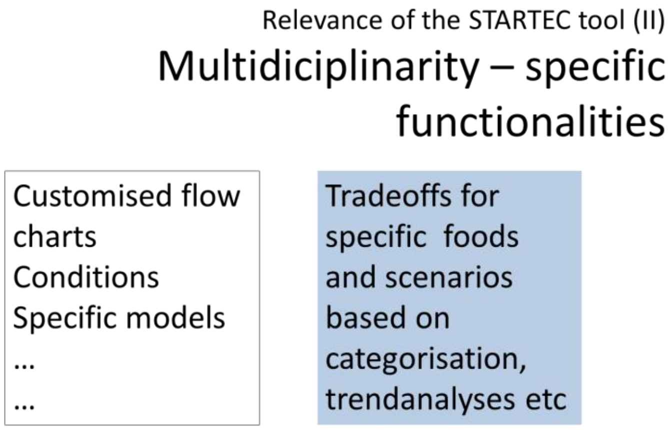

Figure 3. Options for further development of the STARTEC tool as a stand alone tool.

A decision support tool consists of two main parts: the IT part, and the data and models the IT tool is filled with. To include more functionality, relevant data and models are needed. This will be the same for all decision support tools. Generation of relevant data can therefore be done as standalone studies, and be integrated in an IT tool in a second step. Generation of data and models is therefore a third main route for development of the concept of STARTEC, see Figure 4.

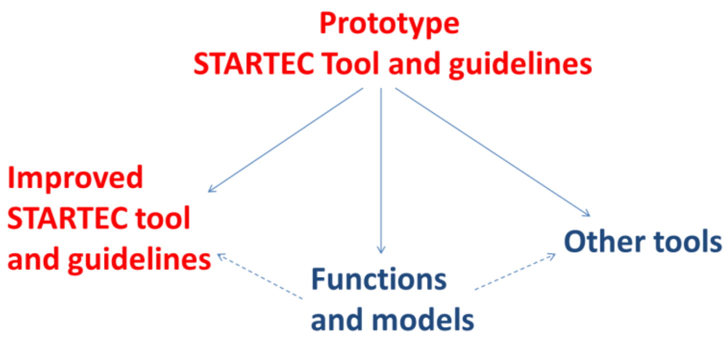

Figure 4: Main routes for development of STARTEC results. The tool can be developed alone, in collaboration with other tools, and models and functions/algorithms can be developed based on new experiments and be implemented in any tool later.

4.1.4.2 Dissemination Activities of STARTEC

STARTEC outcomes have been disseminated to a wide audience using a number of different communication mechanisms: the STARTEC website (www.startec-eu.info); scientific publications; general publications; workshops, seminars; conference oral presentations, posters, and workshops; exhibitions; articles; web applications; workshops and tutorials; postcards; banners; and flyers. Very positive feedback, and a high level of interest in the project, was evident after each dissemination activity. The project successfully brought together researchers of different scientific disciplines both within and external to the project, and there was a very fruitful collaboration between academic and industry partners. This was particularly evident by the high attendance rate of industry partners at STARTEC meetings and events, and their feedback and contributions which were incorporated into the project work. Working links were established with other relevant projects, in particular the EU projects BASELINE, SOPHY, TRADEIT, FRISBEE, PMM-Lab, and SiLeBAT. Cross-fertilisation of ideas and knowledge was facilitated in a number of areas, including food formulations, process mapping, down-scaling of food production systems, modelling, experimental design, microbiological detection methods, food safety and quality, nutritional and quality analyses, economics and cost-benefit analyses, alternative processing technologies, packaging systems, and time-temperature indicators. Two early stage researchers availed of study exchanges, and early stage researchers across the project had the opportunity to present their work at meetings, workshops and conferences. Three PhDs will be completed, based on STARTEC research.

Multiple project events were organised to promote the STARTEC IT Tool and project findings, including a STARTEC workshop at EFFoST 2014, and a STARTEC workshop for industry held in Oslo, Norway. There were four scientific publications published during the project which were related to STARTEC research, four more publications have been submitted, and further publications are planned. STARTEC was also featured in the International Innovation Journal, which communicates research to a broad audience. The consortium worked on new ideas and identified opportunities for further collaboration and funding; several of the project partners have been successful in obtaining further EU project funding. Plans are in place to submit proposals for future national or European programmes, in order to continue the work of STARTEC, based on the project final recommendations and our exploitation plan.

Teknologisk Matforum

For the **industry workshop**, we chose to establish contact with "**Teknologisk Matforum**" in Norway. The organization has approximately 600 members from food producers, suppliers to food industry, consultants and researchers. They organize 6-10 workshops on topics relevant for these groups each year where they invite researchers, food authorities and food companies as speakers to update the industry on upcoming technologies, special challenges related to food safety and regulations, etc. The participants pay a fee for participation on these days, which means that the attendants are dedicated. Workshops in the forum are therefore useful for pilots and discussions. Our workshop was held on the **15th October 2014**.

EFFoST European Federation of Food Science and Technology

For the **research community workshop**, we chose to contact **EFFoST**, which is arranged by Elsevier. The annual conference was held in Uppsala in Sweden on the **25th November 2014**, which was a suitable time to demonstrate the STARTEC IT tool. EFFoST focus on food processing, novel technologies, food safety in an applied context and has a multidisciplinary approach to food research. This is a good mix for STARTEC. We were allowed to arrange a free workshop the day before the conference, and had in addition 7 posters and one oral presentation at the main conference. STARTEC has been presented at several other conferences as well, but EFFoST is the one we chose to present STARTEC in a broad sense. We invited the SOPHY project to give a presentation at our workshop, and established useful contact with them.

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There are plans for two other STARTEC workshops after the end of STARTEC:

The first one is a symposium at the **IAFP conference**, in Cardiff, Wales, UK, on the **22nd April 2015**. This has been arranged by Dr. Taran Skjerdal (NVI) and Dr. Catherine Halbert (HRES) to disseminate STARTEC results for an even broader audience.

IAFP has a similar focus to EFFoST, but with more focus on microbiology. Our workshop is part of the official IAFP 2015 conference programme. We are pleased that the presentations are from our research partners (NVI, UNIBO), one of our industry partners (MBORSEN) and our external advisor from BfR, which provides a good link to the SiLeBAT and PMM-Lab projects.

Presentations will include:

- The STARTEC Tool and Guidelines for Food Producers - Ingredient and Technology Choices for Food Safety, Quality and Nutrition. Taran Skjerdal, Norwegian Veterinary Institute
- Definition of Safety Criteria in RTE products: A Whole Chain Approach from Ingredient Selection up to Consumption. Alessandra De Cesare, Alma Mater Studiorum, University of Bologna
- "A day in the life"- A Food Company Shares its Wisdom. Cecilie From, Matbørsen
- Developing Tools for Food Safety Decision-making - Challenges and Recommendations. Matthias Filter, BfR

A fourth workshop is under consideration in connection with the **EFFoST meeting in Athens in 2015**. This is an initiative from professor Petros Taoukis in the SOPHY project, who is also the chairman of the conference. The intention is to arrange a joint workshop between several projects that have developed tools, and see some months after the projects are closed what has happened with the tools, and see if they can be further developed, together or separately.

Scientific publications - Published/Accepted:

1. Microarray-based transcriptome of *Listeria monocytogenes* adapted to sublethal concentrations of acetic acid, lactic acid, and hydrochloric acid. D.O.I. 10.1139/w2012-091, published in the Canadian Journal of Microbiology. 58: 1112 – 1123 (2012). Authors: Girum Tadesse Tessema, Trond Møretrø, Lars Snipen, Even Heir, Askild Holck, Kristine Naterstad, and Lars Axelsson.

2. Fate of Salmonella enterica in a Mixed Ingredient Salad Containing Lettuce, Cheddar Cheese, and Cooked Chicken Meat. FEDERICA BOVO, ALESSANDRA DE CESARE, GERARDO MANFREDA, SUSAN BACH, and PASCAL DELAQUIS. Department of Agricultural and Food Sciences, University of Bologna, Via del Florio 2, 40064 Ozzano dell'Emilia (BO), Italy; and Agriculture and Agri-Food Canada, Pacific Agri-Food Research Centre, 4200 Highway 97 South, Summerland, British Columbia, Canada V0H 1Z0. MS 14-187: Received 25 April 2014/Accepted 3 October 2014. Journal of Food Protection, Vol. 78, No. 3, 2015, Pages 491–497.
3. Alexandros Ch. Stratakos, Gonzalo Delgado-Pando, Mark Linton, Margaret F. Patterson, Anastasios Koidis. (2015) Synergism between high-pressure processing and active packaging against *Listeria monocytogenes* in ready-to-eat chicken breast. Innovative Food Science and Emerging Technologies 27, 41–47.
4. Alexandros Ch. Stratakos and Anastasios Koidis (2015). Suitability, efficiency and microbiological safety of novel physical technologies for the processing of ready-to-eatmeals, meats and pumpable products". International Journal of Food Science & Technology. DOI: 10.1111/ijfs.12781.

Scientific publications - Submitted:

5. Microbiological Characteristics of Pasta Spelt Berry and Rice Salads and influence of Storage Temperature. M. Trevisania*, A. De Cesareb, R. Mancusia, F. Bovob, S. Vitalib, G. Manfredab. Submitted to International Journal of Food Microbiology.
6. Microbiological and mathematical approach to derive Performance Objectives for Bacillus cereus in Ready To Eat salads. Alessandra De Cesare, Silvia Vitali; Marcello Trevisani; Federica Bovo; Gerardo Manfreda. Submitted to International Journal of Food Microbiology.
7. Alexandros Ch. Stratakos, Gonzalo Delgado-Pando, Mark Linton, Margaret F. Patterson, Anastasios Koidis (2015). Industrial Scale Microwave Processing of Tomato Juice using a novel Continuous microwave system. Submitted to Food Chemistry.
8. Gonzalo Delgado-Pando, Alexandros Ch. Stratakos, Anastasios Koidis (2015). Ascorbic acid content of ready-to-eat wheat-based salads. Effect of processing, packaging and storage temperature. Submitted to Food Chemistry.

An article about STARTEC entitled 'Ready to Eat?' was also published in the **International Innovation Journal** issued October 2013. This Journal is aimed at a general readership.

STARTEC project partners have been actively developing new proposals and applying for national and European funding calls. Relevant successes include:

- **Partner HRES**: Project **TRADEIT**, funded under FP7-KBBE.2013.2.3-02: Network for the transfer of knowledge on traditional foods to SMEs. There has been collaboration via the STARTEC partner Dr. Catherine Halbert, project manager and Leader of 'Knowledge Transfer' in TRADEIT.
- **Partner UNIBO**: Project **COMPARE**. Successful in obtaining funding in H2020 as a partner in the grant 643476 COMPARE under the PHC-07-2014 Improving the control of infectious epidemics and foodborne outbreaks through rapid identification of pathogens.
- **Partner NVI**: Project **FoodPathChain**. NVI are a partner in a Norwegian strategic research program (FoodPathChain) where pathogens in foods during processing in a pilot plant particularly developed for this purpose. STARTEC was a basis for the proposal and some of the topics in STARTEC will be further studied in the project.

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- Partner **IRIS**: Our partners in IRIS are involved in multiple EU and private projects relevant to the food industry (see full list at http://iris.cat/projects/).

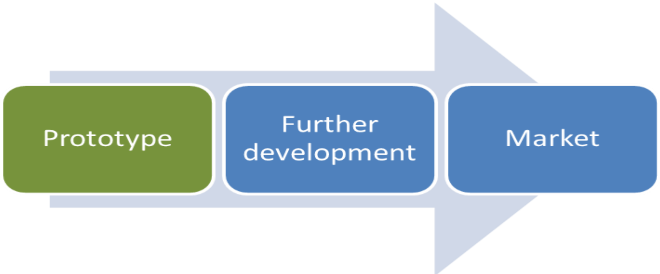
4.1.4.3 Exploitation Plan for STARTEC

IP Status of STARTEC: To date, there have been no patent applications or such protection methods applied to any of the project results. By the time the project is closed, we do not expect any results subject to IP protection. The project results will be disseminated according to the dissemination plan, including guidelines for industry and scientific publications. The prototype software application, the STARTEC IT Tool has been developed using different open source development tools. No thorough assessment has been made with regards to the commercial use of this software, but as an example, "MySQL" (the database of the IT Tool) is subject to licensing fees to Oracle in case the database will be used commercially. The different license agreements of platform that the IT Tool has been built on (and with) needs to be audited to understand any licensing restrictions to commercial use, if any.

As the objective of the project is to build a prototype and the project is about to close, a natural development is to start the discussion on how and if we can exploit the results commercially.

Where to go from here?

The STARTEC project has generated an excellent starting point for the road ahead. We have solid scientific data, list of stakeholders, dissemination plans and a prototype application. The challenge now is to utilise all this so that further development can be funded and eventually introduced to the market. To understand what is required, we should make a business plan that will address the most important elements we must consider.



Business plan:
The Business plan will help us in defining clearly what the tool should become, who will use it and how we can make it to the market. Independent of the source of funding, it will address the key elements that a potential sponsor will look for in a proposal. In the following, the key elements of a business plan is outlined.

Service offering: We need to consider the service offering and pricing. We must also consider the functionality needed by stakeholders and what the end-users want to see in a «finished product»? We have agreed that the following are needed:

- More scientific models and products to choose from (requires research contribution)
- More functionality that links database, models and simulations better than today.

Marketing Plan: Market research would need to be conducted to include market research, market economics, identification of the customers, exploration of competing products, and to determine how and what do we promote.

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Who are the potential stakeholders and users of the tool if it's developed into a commercially available service, and what service offering do we believe the tool needs to provide?

- Food producers wanting to assess their own production
- Regulatory bodies (Food safety agencies) wanting to assess food production in companies in general
- (Food Safety) Consultants in the business of counselling food producers
- Laboratories wanting to create trend analyses
- Risk assessors wanting to create trend analyses and exposure studies
- Anyone wanting to provide qualified data to the database
- Other stakeholders who want to work together based on the information in the database.

Management and Organization: "The How To" – operational plan. We need to identify who will develop the prototype further, for example: scientific partners providing data for new products and processes ("wetlab"); and IT expertise and modelling expertise for translating data to models and enable compatibility with other tools (or establish industry standard platform).

Financial Plan: Who do we believe will provide financing? Who to we target for funding?

- Industry partners (not only one – need to secure accessibility for wide range of stakeholders)
- Public funding. Some opitions are National research innovation funding. EU research and innovation funding (Horizon 2020). In terms of H2020, we intend to seek funding in particular within Societal Challenge 2 'Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy' and 'Innovation in SMEs'. Other opportunities may be possible within the Marie Skłodowska-Curie Programme.
- Private venture capital.

Timeline and alignment with other projects and tools

Several other tools, also some prototypes, are currently being developed. It will be useful to link with these and more established tools to explore options. The STARTEC team has decided the following future steps.

- A workshop at the IAFP conference in Wales (April, 2015), where several other tools will be presented and there will be opportunities to discuss future development.
- A meeting in Oslo (June 2015) between the STARTEC partners interested in participation of further development of the prototype tool. External experts involved in STARTEC will be invited. The meeting will build on the exploitation plan, and the purpose is to decide ways forward, if we go forward as one team or several smaller ones, discuss options for funding, etc. So far, the Innovation in SMEs program in H2020 seems to be a relevant instrument.
- A workshop at EFFoST in Athens (November 2015) together with other developers of tools for ready-to-eat foods. The initiative to this workshop comes from the SOPHY project, which was funded under the same call as STARTEC. The purpose is to explore whether different tools should be developed on their own, or in collaboration.

In addition to these meetings, a spin-off project is running where some of the observations in STARTEC in small scale will be tested in pilot scale. A number of H2020 and EU funding programmes could facilitate further development of STARTEC outputs, in particular: **Marie** Skłodowska-**Curie** actions; Innovation in SMEs; Societal Challenges; and COST Actions.

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