FRAUNHOFER INSTITUTE FOR SYSTEMS AND INNOVATIONS RESEARCH ISI

ROADMAP PULSED ELECTRIC FIELD (PEF) PRESERVATION

THE I³-FOOD CONSORTIUM

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THE I³-FOOD PROJECT

The i³-food project achieves an optimum process control, leading to application of three food processing technologies under real life operating conditions. This is done by demonstrating and piloting in a near to operational environment of applicable validation systems for each technology. We are defining a scientific and cutting edge strategy for overcoming the market barriers ensuring a fast and wide market uptake. Finally, our multidisciplinary endeavor is connecting and amplifying the EU strengths in advanced technology research. This project is supported by the Horizon 2020 EU Research and Innovation programme.

Novel food processing technologies have been further developed in recent years and decades. Although technical advantages have been made in terms of time savings, energy savings, extending of shelf life for retailers and 'ready to use' products, the implementation of these technologies in industrial food production is often still rather limited. The reasons for that are manifold and vary from low acceptance or rejection by consumers (e.g. ionizing radiation of food), to non-open market access or lack of knowledge and information among food producers on how to integrate novel technologies. An applicable validation system for integrating these technologies one by one based on a generally approach is missing. Taking the risk and investing in an improvement of their processing lines is one of the main hurdles for the industry, especially for small and medium-sized enterprises (SME) in food processing. There is neither the time nor the resources available that are needed for the implementation of new non-standard processes.

The overall objective of i³-food is the implementation of three prioritized innovative food processing technologies by validation of optimum process control under industrial conditions.

Three technologies prioritized in i³-food are:

- Pulsed Electric Field preservation (PEF-P) of liquid food products (e.g. fruit juices or smoothies)
- High Pressure Thermal Sterilization (HPTS) for ready-to-eat-meals
- Low Shear Extrusion of cold food products (ice cream).

A connatural set of both, technical (missing online sensors) and process-conditioned bottlenecks exists, which hinders their uptake by industry and into the market.

Therefore, optimum process control will be achieved in i³-food leading to application under real life operating conditions by demonstrating and piloting in a near to operational environment of applicable validation systems, for each technology.

For rapid and easy market penetration an analysis of the innovation environment and identification of opportunities have been performed, leading to roadmaps for market uptake (one roadmap per technology). This integrated approach is providing maximal synergies in between the three afore-mentioned technologies. The summary of one roadmap is shown in this brochure.

Comparison of green smoothies

PULSED ELECTRIC FIELD (PEF) PRESERVATION OF LIQUID FOOD PRODUCTS

The pulsed electric field (PEF) technique inactivates microorganisms in liquids to increase shelf life and the gentle, low temperature processing character ensure, that freshness and quality are retained. The PEF technology for the physical poration of the cell membrane was first described in 1960. It has been shown that a product-friendly prolongation of the shelf life of food products as well as a structural modification of biological material are possible. After the clarification of the mechanisms of action, the discovery of the versatile application possibilities and the technical development of components, the time was ready for an industrial implementation in 2006. The biggest hurdle was now to make the technology, that was only on-hand in laboratory scale, available for industrial use and to meet the prevailing framework conditions with regard to treatment performance, reliability as well as hygienic design. There are only very few companies in Europe developing and distributing PEF equipment which are mainly SMEs. These companies and their supplier industry will clearly benefit from a higher market penetration of the technology.

The innovation potential in the field of PEF lies in a wider implementation of this technology for the preservation of pumpable food products. Traditional thermal pasteurisation causes destruction of health promoting ingredients, such as vitamins, and leads to loss in fresh flavour. The application of PEF allows a preservation of heat sensitive products, such as juices or smoothies where the fresh taste is the main quality parameter, without or minor effects on the quality (see the figure above, comparison of fresh, PEF treated and thermal treated green smoothie). The continuous operation and simple equipment design with different possible capacities enables an easy implementation in existing production lines.

The main application for PEF pasteurisation is for fruit and vegetable juices. In 2011, 10.7 billion liters of fruit juice (of which 1.7 billion premium, not from concentrate) have been consumed. Germany (2.7 million liters) and France (1.7 million liters) are the largest juice markets. Approx. 650 European fruit juice producers have created a turnover of 8.9 billion Euros per annum. The majority of companies are small and medium sized enterprises. In recent years the share of chilled products with a short shelf life has increased and a diversification towards a broader number of flavours and mixtures is observed, both challenging production management and distribution chain. Extension of shelf life by PEF e.g. from 7 to 21 days for orange juice allows better production management and overall economic improvements. In addition to a premium juice quality, the possibility to increase production batches size, reduce cleaning efforts and retail waste, as well as increased market reach allow a 10 to 15 per cent cost benefit in comparison to conventional processing. Other possible application includes dairy industry (consumption or cheese milk preservation, whey protein etc.) with a turnover of 117 billion Euro or culinary products (preservation of sauces, dressings etc.) with a turnover of 12 billion Euro per annum on a European level.

An industrial Elea PEF CoolJuice system with capacity of up to 5000 l/h

Currently only innovative driven and rather small and medium enterprises risk the application of PEF-Preservation. Main hurdles at this stage are a lack of standardized process validation and control options as well as clear guidance how to fulfil relevant food legislation for PEF treated food products.

Online evaluation of the important process parameters for intensity (electrical field strength, specific energy and temperature) is crucial to guarantee production of safe products with high quality. Process benefits are independent on product categories and also could be transferred into other industries such as biotechnology and pharmaceutical industry where less thermal intensity during pasteurisation (media for fermentation, vaccines etc.) is beneficial.

PEF is in a transitional phase towards a state of the art application for premium quality liquid food products like fruit juices or smoothies and is already used on a commercial scale (see Figure above). Unique advantages have been demonstrated both, for producer and retailer, especially due to extended shelf life and reduction of retail waste. Despite this advantage, application is still limited on a group of innovative but relatively small SMEs. In contrast, big players in the juice and soft drink industry are carefully watching the technique development, as standardized process validation and control options are not available yet. Continuous discussions with first users of this technology as well as with enterprises generally open to innovation, have revealed that the lack of process guidelines to fulfil the relevant food legislations is one if not the most dominant factor hindering a broader application of PEF.

In general, processors require a HACCP concept, identifying critical control points, process conditions and monitoring tools. As PEF is a technology with multiple process and operation parameters (electric field strength, pulse waveform, energy input, temperature) no general dose concept to describe and monitor treatment intensity and its distribution is available so far. Present users of the technique have identified their own, application specific concept for process monitoring, which requires a high level of technical and scientific background as well as case by case discussion with food authorities. The development of a standardized, on-line process monitoring concept based on specific energy delivered and detection of treatment intensity distribution is crucial.

PEF treatment intensity can be characterized based on initial temperature, energy delivery and temperature after treatment. Due to treatment chamber, configuration and product viscosity, a three-dimensional, spatial treatment intensity matrix results. Whereas the overall energy delivery can typically be detected by pulse monitoring, its spatial distribution can only be indirectly measured by temperature increase. Due to the presence of high electric field strength, conventional thermocouples can only be applied far away from the application area. The use of fibre optic sensors in contrast allows temperature detection in the treatment zone. Selection of suitable positions for temperature measurements, implementation of sensors and online data analysis are core elements for the application of a standardized HACCP-concept.

Despite suitable fibre optic sensors are available, their use to develop a standardized HACCP concept needs to be demonstrated. The robustness of the process monitoring concept e.g. in cases of deviation of inlet temperature or product flow will have to be challenged and validated. The final step will be the elaboration of action guidelines for situations of detection of under-processing. On the whole, it is the purpose to develop an online tool to monitor treatment intensity and its distribution, based on temperature monitoring to control continuous PEF-preservation applications and ensure process and product safety.

ROADMAP PULSED ELECTRIC FIELD PRESERVATION (PEF)

TIME ▶ 2017 | PREDICTABLE | 2020 | F

DRIVERS & BARRIERS

MARKET

- **M-B1:** Novel Food question
- **M-D/B1:** Food safety
- **M-D4:** New and different product concepts
- **M-D6:** Clean
- **M-D1:** Shelf-life extension from 1 to 3 weeks
- **M-B2:** Limited range of products
- **M-B5:** Consumer acceptance of PEF-treated food
- **M-D3:** Fresh/minimally processed product
- **M-D5:** Sustainable due to less food waste
- **M-D2:** High nutritional quality
- **M-B3:** Proper labeling for PEF treatment
- **M-B4:** Consumer perception of fresh food

TECHNOLOGY

- **T-B1:** Case specific optimization of settings
- **T-D2:** Fits in existing processes
- **T-B4:** Adaption need for filling devices (aseptic filling) and packaging methods
- **T-D5:** Continous proces
- **T-B2:** High investment in the technology
- **T-B3:** Release of materials from electrodes
- **T-B7:** Not enough scalin possibilities
- **T-D1:** Fresh attributes of the food (better sensory attributes)
- **T-D4:** Higher packaging flexibility
- **T-D/B2:** High quality ingredients needed
- **T-D/B1:** No enzyme inactivation
- **T-D3:** More easy cleaning
- **T-B5:** Pulse analyses requires further development
- **T-B8:** Applicability singular liquids
- **T-B6:** Multiple process parameters
- **T-B9:** High costs of researc initial implementation

POLICY

- **P-B2:** Novel Food legislation
- **P-B1:** IPR/only a few technology producers/patent situation
- **P-D1:** S distribu
- **P-B3:** Labelling needs
- **P-D/B1:** Food safety
- **P-D2:** Innovative tech

MEASURES

INDUSTRY

- Economic Picture (T-B2, T-B10)
- Limitations of the application (food safety) (T-B10)
- Focus on research to support the application of the technology (M-B1, T-B11)
- Packagi by asep T-D4)

RESEARCH

- Research for technology development (scaling up, combination processes) (T-B6, T-B7)
- Comparative studies to existing treatments (M-B1, M-D1, M-D2)
- Make ple to understand/operate (T-B9, T-B11)
- Research on gaps on regulation (food matrices) protective effects (M-D1, M-D2)
- Research mate science, electr chemistry (T-B

POLICY

- Labelling → communication of actors (P-B2, P-B3; M-B1, M-B3, M-B4)
- Consumer perception of PEF-treatment (M-B4)
- EU database on PEF applications
- Dialog b science, and ind ogy pro users (M

■ Driver
■ Barrier
(M-Measures) adressed Driver/Barrier

MARKET LAYER includes Customers, Competitors, Users
TECHNOLOGY LAYER includes Features, Processes, Costs, Performance
POLICY LAYER includes Regulation, Legislation, Investment, Funding

FORESEEABLE | 2025 | PROBABLE | 2030

& clear label

s

T-B10: High operational costs

T-B11: Standardization needs for equipment and for production process

ng up

T-D6: Production process efficiency

only for

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ustainability during the
tion and storage process

nology

ng information
tic filling (T-B4,

erial
ical,
3)

To come with new applications (M-D4)

Indicator strains for PEF (M-D1, M-B1)

Studies substantial equivalence (M-B2, M-B1)

Standardization of processes/equipment (T-B11)

Research on benefits (sustainability, health) (M-D1, T-D3, T-D4, T-D5, T-D6)

between
policy makers
ustry, technol-
viders and end
M-B1, M-B2)

i3 FOOD New treatments for better food

Fraunhofer ISI

FOOD VALUE CHAIN AND POSSIBLE MEASURES

For a deeper understanding of the opportunities and hurdles of the technology, the food value chain for PEF was investigated. A schematic picture is shown in the figure below.

Possible measures to address drivers and barriers are shown in the roadmap. These items show options for industry, research and policy stakeholders to improve and foster a faster market uptake of the technology. These measures are described briefly in the following paragraphs:

INDUSTRY DIMENSION

- **Economic Picture**
  Investment required, cost/benefit information in industrial scale.

- **Limitations of the application**
  There is a need to optimize each product by redesigning the process. The limits of the product (particle size) and food safety require further industrial research

- **Focus on research to support the application of the technology**
  Increase resources on new developments to improve application on the market.

- **Packaging information for aseptic filling**
  What are the limits in packaging formats for the technology? Are they already described? More details are necessary for industry.

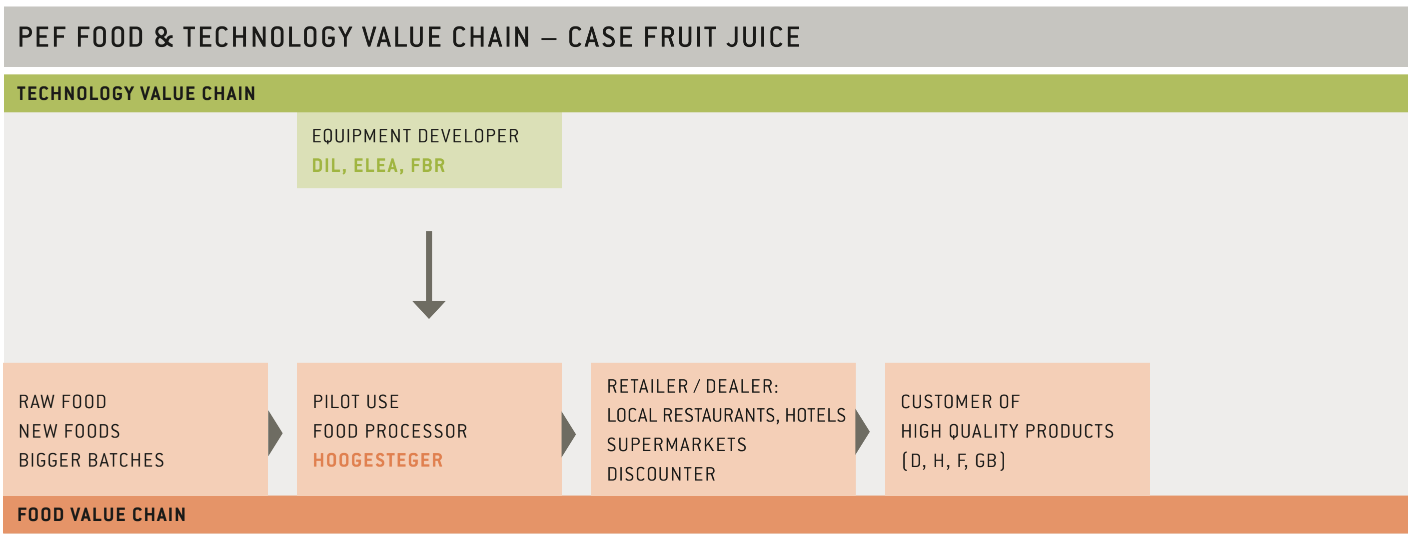
RESEARCH DIMENSION

- **Research on technology development (up-scaling, combination processes)**
  Development of a technology optimization process and combine processes for effects e.g. on microorganisms or far reducing costs

- **Comparative studies to existing treatments**
  A basis for comparison has to be defined. Subsequently studies have to be performed.

- **Make the technology more simple to understand / operate**
  Due to peculiarities for different products the technology is perceived as to be very complicated. This hinders the implementation.

- **Research on gaps on regulation (food matrices) protective effects**
  Interaction between treatment and the food matrices has to be further investigated (protective stimulating)



- **Research material science, electrical, chemistry**
  Proof that there is no risk with electrode materials. Research new materials of electrodes, as well as electrical reactions near electrodes.

- **To come up with new applications**
  New possibilities of PEF in yield improvement, solid foods, foods with particles, non-food, biotechnology.

- **Indicator strains for PEF**
  Is there a need for specific strains to measure effect of PEF or could the standard indicators be used? Need for more research on mechanism of PEF and microorganism.

- **Studies substantial equivalence**
  Novel food legislation specifies substantial equivalence. Need for good studies to proof PEF products are not substantial different from existing product.

- **Standardization of processes / equipment**
  Development of sensors (e.g. i³-food), standardization on effect of PEF to micro-organisms, enzymes. These conditions result in 5log reduction of specific micro-organism in the final product.

- **Research on benefits (sustainability, health)**
  The research should focus as well on benefits of the technology like health (bio availability) and sustainability.

POLICY DIMENSION

- **Labeling / communication of actors**
  Labeling needs of PEF treated food have to be clarified to make it easier for industry to use the technology and for customers to have maximal transparency.

- **Consumer perception of PEF-treatment**
  Policy could increase the perception of the advantages of PEF treated food (health issues).

- **EU database on PEF applications**
  A database on applications of PEF could help to reach faster market uptake.

- **Dialog between science, policy makers and industry, technology providers and end users**
  Unclear situation, users are unsure what to do / how to do.

ROADMAPPING METHODOLOGY

Roadmaps are increasingly used as a management technique for supporting innovation, strategy, and policy at firm, sector, national and international levels. Throughout its long history the roadmapping approach has evolved, firms and other organizations have adapted the concept to address their particular needs and the changing business context. Roadmaps provide decision-makers from business, science and politics with a structured overview of market developments and framework conditions, such as drivers and barriers, along with information on relevant products, technologies, and competences representing state of knowledge and their corresponding relationships.

The outcomes of a roadmapping process are graphical representations of these objects along the timeline, which links the current development trends to the future. Furthermore, roadmaps include measures and activities to address the relationships between market developments and technologies. The most important benefits of roadmapping processes are:

- The roadmap is an ideal form to display a lot of complex and interrelated information in a single picture.
- Certain patterns of interpretation are typical and unique for a roadmap. If inconsistencies are detected solutions can be discussed directly, thus 'hot topics' and 'blind spots' become visible. All these interpretations allow to define actions and to design a strategy accordingly.
- Roadmaps support strategic communication within and between firms and organizations, and the inherent flexibility of the method, which can be readily customized.

For this project, an approach of a roadmapping process was conducted based on workshops with consortium members and technology as well as marketing experts from the involved industry partners. The experts discussed assumptions about market demands and further relevant developments as well as identified opportunities and barriers and their future developments. Finally, they identified the most important measures to enable a successful market penetration. This was done in two steps:

SCOPING WORKSHOPS

- Assessment of the opportunities and barriers as well as gaps or further requirements.
- Identification of the most relevant technology applications, which are not yet obvious but could possibly occur in the future.

ROADMAPPING WORKSHOPS

- Assumptions about the future development of market demands and further relevant developments.
- Identification of the most important measures to enable a successful market penetration of the technologies.

ROADMAPPING METHODOLOGY

SCOPING WORKSHOPS

- Assessment of the opportunities and barriers as well as gaps or further requirements
- Identification of the most relevant technology applications, which are not yet obvious but could possibly occur in the future

OBJECTIVE:

REACHING A CONSESUS ON THE CRUCIAL FRAME CONDITIONS THAT HAVE TO BE CONSIDERED IN THE ROADMAPS IN ORDER TO ENABLE A SUCCESSFUL MARKET PENETRATION

ROADMAPPING WORKSHOPS

- Assumptions about the future development of market demands and further relevant developments
- Identification of the most important measures to enable a successful market penetration of the technologies

OBJECTIVE:

ENSURING A COMMON UNDERSTANDING AS A BASIS FOR A STRAIGHT IMPLEMENTATION OF THE IDENTIFIED MARKET UPTAKE STRATEGIES

ROADMAPS

PULSED ELECTRIC FIELD PRESERVATION (PEF-P) OF LIQUID FOOD PRODUCTS	HIGH PRESSURE THERMAL STERILIZATION (HPTS) OR PRESSURE ASSISTED THERMAL STERILIZATION (PATS)	LOW SHEAR EXTRUSION OF COLD FOOD PRODUCTS (LS-EXTRUSION)

IMPRINT

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