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The FRISBEE expected results

The project will develop new innovative mathematical modelling tools that combine food quality and safety together with energy, environmental and economic aspects to predict and control food quality and safety in the cold chain.

We expect FRISBEE to contribute to reductions in energy consumption in refrigeration processes. Worldwide, refrigeration consumes 8% of all energy and is responsible for 2.5% of greenhouse gas emissions; therefore any reduction in those figures will be a big improvement.

FRISBEE is a Refrigeration Innovation for Food Cold Chain Research European project IP. The four-year, 6 M euro project is funded mainly through the EU's 7th Framework Programme.

We have begun by developing a comprehensive database on the cold chain in Europe, identifying refrigeration needs and available current technologies in the food industry, and investigating consumer needs and expectations with respect to the food cold chain.

FRISBEE Partners

26 partners comprising 13 companies, 11 research institutes or universities, and 2 non-governmental organizations.

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NEWS

Frisbee industrial workshop at 3rd IIR International Conference on Sustainability and the Cold Chain

Frisbee partners held an industrial workshop in the UK recently alongside the 3rd IIR International Conference on Sustainability and the Cold Chain. The workshop attracted approximately 60 attendees with a truly international audience from far afield as the USA, New Zealand, Japan and China.

Attendees were presented with a range of results from the Frisbee project covering superchilling, magnetic refrigeration and integrated modelling. Information was also presented on industrial and consumer needs that have driven the work within the Frisbee project. Many of the Frisbee partners stayed on after the workshop to attend the IIR International Conference on Sustainability and the Cold Chain and presented papers from the project. In all 8 papers on the work carried out within the Frisbee project were presented covering results from the field trials, the integrated modelling and work using heat pipes and phase change materials.

Update on FRISBEE Cold Chain Database and tools

In order to gain a greater insight into deviations between real cold chain data and targeted specifications, a web based platform for building the first European Cold Chain Database has been set up! More than 12.500 time temperature profiles have been contributed so far from more than 150 data sources on refrigerated and frozen foods. The Database is dynamically growing due to a continuing active contribution from FRISBEE consortium members and third parties.
The Database is publically available at www.frisbee-project.eu/coldchaindb
Focused field tests were performed throughout Europe: Greece, France, Hungary, UK and The Netherlands. The main goal to collect real temperature data, from production to consumption, on the food cold chain was successfully accomplished! All collected field test temperature profiles are NOW available in the Cold Chain Database.
The FRISBEE Cold Chain Database is accompanied by the Cold Chain Predictor software that draws data from the Database to simulate most probable time temperature conditions for cold chain stages and food products specified by the user, as well as estimation of remaining shelf life at any point of the Cold Chain.

RESEARCH

The FRISBEE tool, a software for cold chain assessment

Food quality, energy use, and Global Warming Impact (GWI) are three important aspects of cold chain performance. Models for different quality indicators (for different food products), energy use, and GWI were developed within the FRISBEE project. The FRISBEE tool was developed by combining software codes for these three classes of models, together with software codes for product heat and mass transfer models, and integrating into a user-friendly graphical user interface. In addition, software codes based on models for predicting the impact of new and emerging technologies (e.g. Vacuum Insulation Panels, Phase Change Materials, superchilling and supercooling) on energy consumption and/or product quality were implemented in the FRISBEE tool.

The FRISBEE tool can be used to evaluate cold chain performance by predicting quality evolution, energy use and GWI for a given cold chain. It can be used to assess the influence of different refrigeration parameters (e.g. set point temperature, evaporation and condensing temperatures, compressor efficiency, fan power, refrigerant type, outdoor temperature) on cold chain performance. In addition, the FRISBEE tool can be used to predict the impact of randomness in temperature and product characteristic on the evolution of product quality along the cold chain.

Developing novel breakthrough technologies

The technologies that have been examined within the FRISBEE project are:

1. **Superchiling and supercooling:** Superchilling has been shown to be a viable technology for storage of salmon and pork. Supercooling of pork has been achieved but some stability problems were encountered. The energy requirements within the superchilled, supercooled and conventional chilled and frozen cold chains has been examined using the reference cold chains developed within Frisbee. This has shown that supercooling uses slightly less energy that superchilling but both compare favourably with conventional chilling (see table below). As both superchillied and supercooled samples were shown to have attractive storage life and quality attributes, compared to conventional cold chain products, the technologies look potentially viable for future exploitation.
2. **Air cycle refrigeration:** Air cycle has been shown to be a viable technology for low temperature freezing. There is still work required to develop working systems but the technology had significant energy and carbon savings when applied at low temperatures compared to conventional technologies.
3. **Nano encapsulated phase change packaging:** Phase change materials were successfully nano encapsulated in packaging materials that can be used in the cold chain to stabilise food temperatures.
4. **Magnetic refrigeration:** The components and their incorporation into a magnetic refrigerator were investigated within the project. It is expected that a magnetic refrigerator will be produced before the end of the project and will be available to view (together with other work package 5 outputs) at the Frisbee demonstration day (29 August 2014).
5. **Vacuum insulated panels (VIPs):** A thermal model of typical refrigerating and freezing appliances was created to assess the impact of VIPs embedded in the walls of refrigerated appliances. The potential energy savings and payback times were then calculated. It was found that VIPs had benefits where space was limited but that production costs need to reduce for the technology to be widely applied.
6. **Nanoparticles:** The potential of nanoparticles to enhance the performance of refrigeration systems has been examined. Even though they have enormous potential, issues associated with the handling of nano materials and questions regarding health and environment were raised.

Cold chains:	Energy estimate (kJ/kg)	
	Salmon chain	Pork chain
Chilled	3434.0	1144.8
Supercooled	3436.5	1230.7
Superchilled	3603.5	1494.9
Frozen	15783.1	13536.8

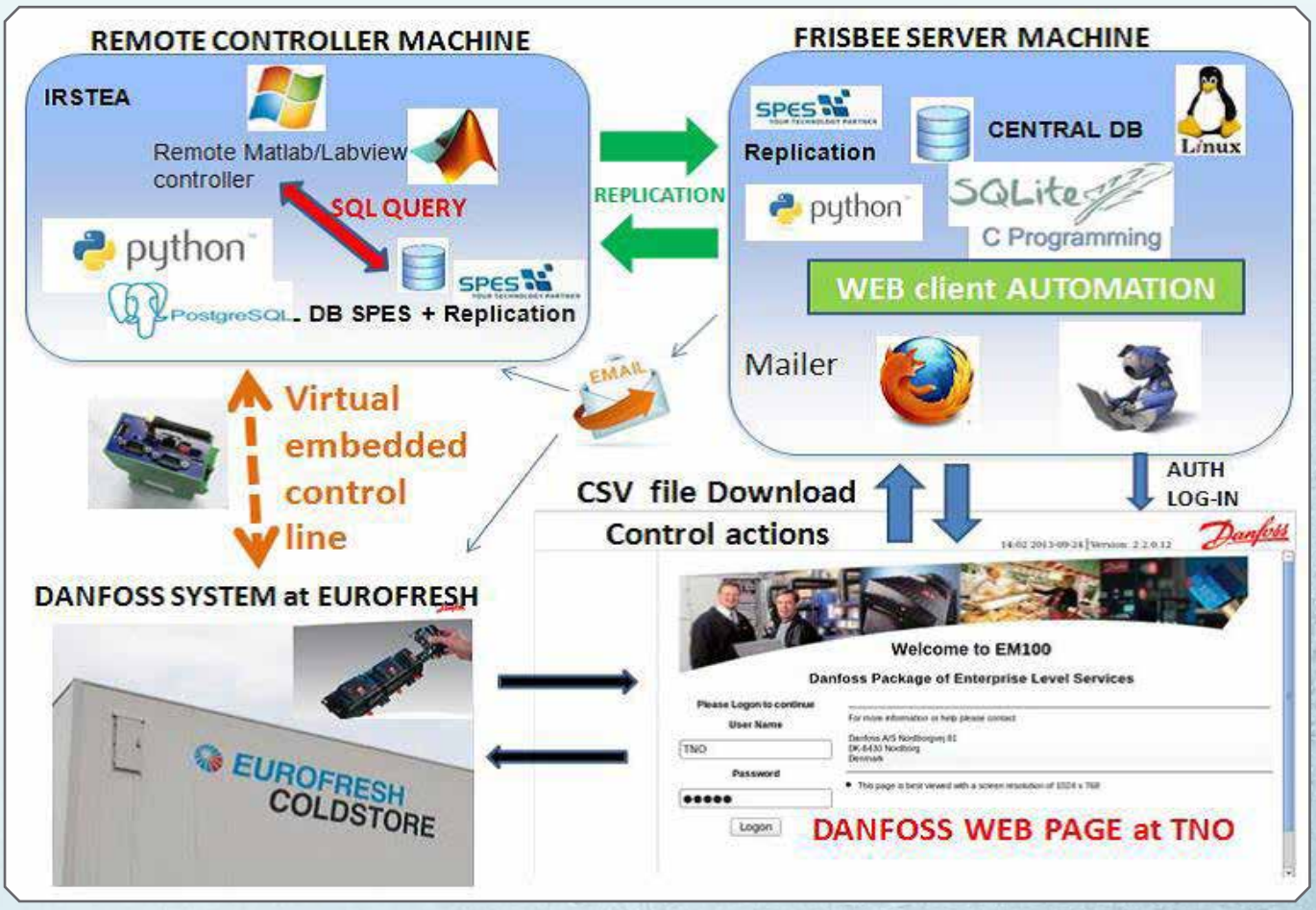
Decisive technological contributions to the development of the most suitable refrigeration technologies for the future

The following results have been achieved within the FRISBEE project to develop and showcase a number of decisive technological contributions to the development of the most suitable refrigeration technologies for the future:

- **Advanced temperature control by PCM,** smart control and advanced packaging for supercooling of pork and salmon and shows that this is promising and gives higher temperature stability and prevents rapid temperature increase of the products.
- **Apple storage with advanced control DCA.** Validating the model and controller of DCA shows that with accurate control of the RQ-DCA unit and carefully

selected fruit (container experiments significant improvements in firmness preservation can be attained. The method performs better than conventional ULO and is at least comparable to other storage DCA methods, such as based on chlorophyll fluorescence measurements. In pilot scale cool rooms, with a mix of fruit from different growers and more effects of air leaks, the RQ-DCA protocol did not show significant improvements yet. This indicates that care should be taken to perform DCA on more uniform batches of fruit and in premium cool rooms that have a high level of air tightness and gas supply control.

- Report on **temperature stabilisation in frozen food** chains,the best solutions for temperature stabilization is a close protection the "Packaging" solution brings no additional energy consumption.
- **Superchilling/supercooling optimization with WINtix based simulation programme** allows to compute the ice crystal size tofor various salmon and pork freezing processes.
- **Control algorithm for cold store.**
  A control algorithm was developed to manage the energy performance of an installation, but the energy savings potential when the controller is running, based on daily simulations, is evaluated between 5 to 10%.
- **Storage ice cream with PCM cover,** in case of temperature abuse, storage with carton box + PCM cover was more efficient to protect the products than isolated box, then carton box.
  A domestic fridge-freezer using PCMs has been and tested rigorously and compared against current technology. Consequently, a total energy consumption of 585 Wh/24h was obtained in the refrigerator prototype. Hence, total energy consumption of the refrigerator prototype has been decreased 2.8% with the PCM application.



Life cycle assessment (LCA) applied to SUPERCHILLING PROCESS of SALMON

Life cycle assessment (LCA) is a standardized methodology (ISO 14040-14049) for assessing the environmental aspects associated with a product, technology or activity over its life cycle. LCA was applied to the chilling and superchilling salmon cold chains in order to compare these two processes and study their environmental impact. The superchilling cold chain presents an important improvement of environmental impact. We observed a diminution of about 20% of environmental impact in all categories is presented in Figure 1 and compared to the regular chilled one. This improvement is mainly due to the augmentation of available volume for transportation in superchilled cold chain since no ice is needed.

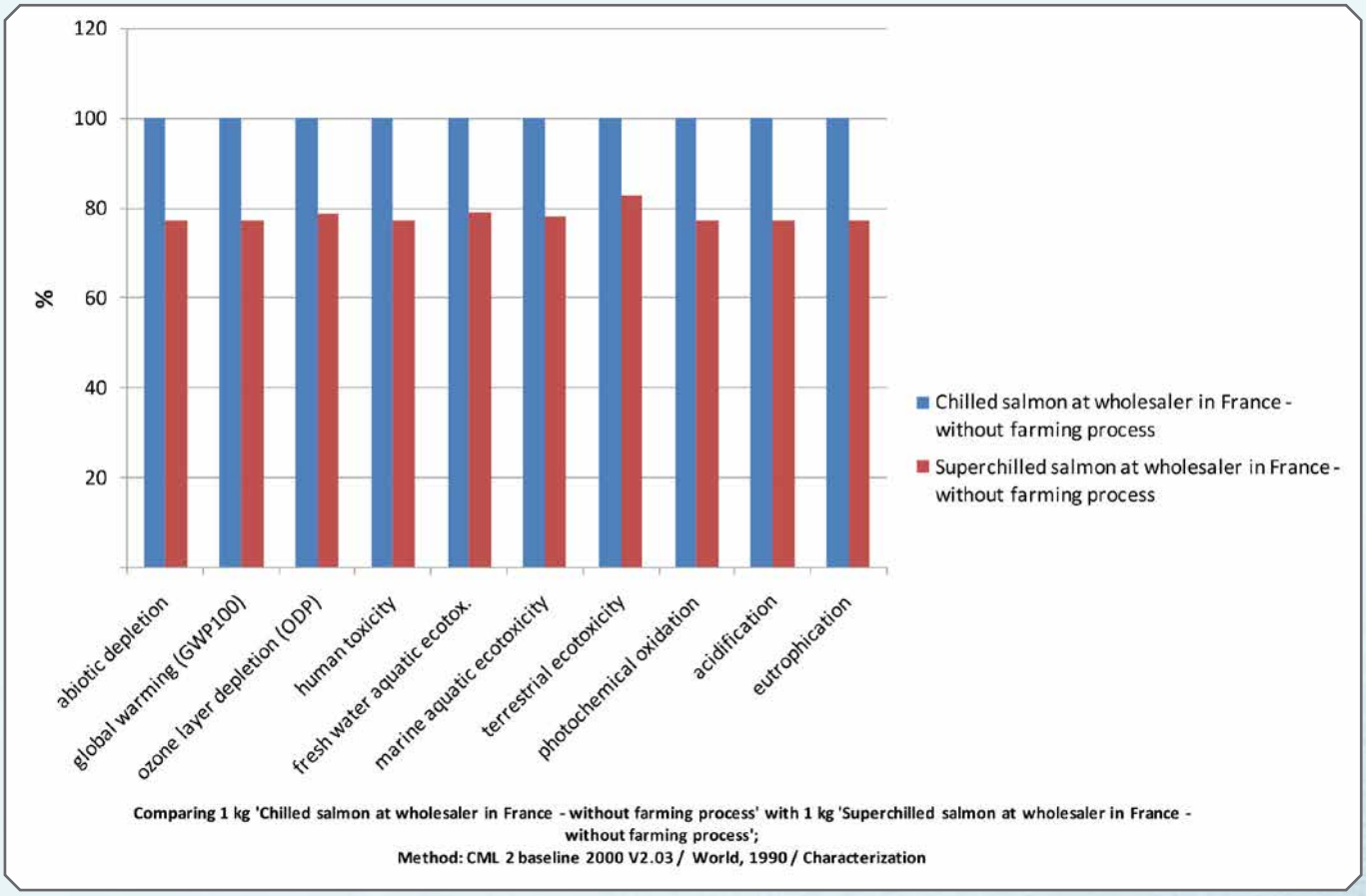


Figure 1: *Comparison of environmental impact between chilled/superchilled cold chain*

UPCOMING FRISBEE EVENTS

Date	Name of the Event	Organised by	Location
29 August 2014	FRISBEE Demo Day	FRISBEE	Paris (France)
16-22 August 2015	The 24th IIR. International Congress of Refrigeration. Improving Quality of Life, Preserving the Earth	IIR	Yokohama (Japan)

www.frisbee-project.eu

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