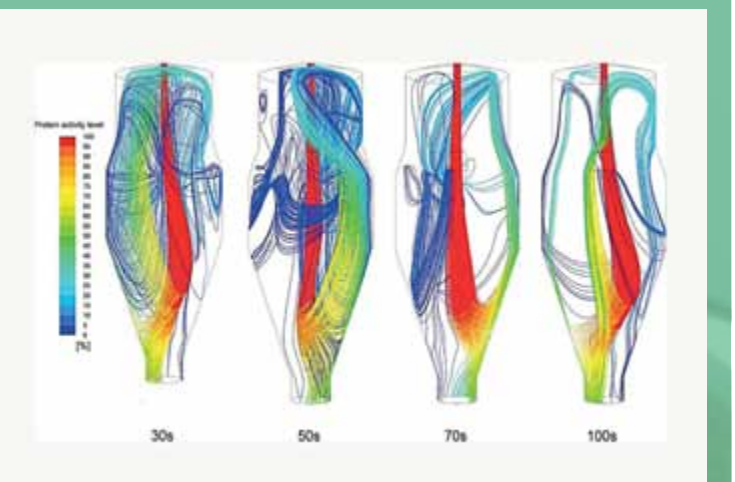
ENTHALPY



INNOVATIVE TECHNOLOGIES REDUCING ENERGY & WATER CONSUMPTION IN MILK POWDER PRODUCTION

EXECUTIVE SUMMARY

WWW.ENTHALPY-FP7.EU

WELCOME BY PIETER DEBRAUWER

MILK POWDER IS AN ESSENTIAL INGREDIENT FOR INFANT FORMULA AND A WIDE RANGE OF DAIRY-BASED PRODUCTS. 152 MILLION TONS OF MILK ARE PRODUCED IN EUROPE EVERY YEAR.

HOWEVER MILK POWDER PRODUCTION IS ONE OF THE MOST ENERGY INTENSIVE PROCESSES IN THE FOOD INDUSTRY! THE ENTHALPY PROJECT WAS SET UP TO SIGNIFICANTLY REDUCE ENERGY AND WATER CONSUMPTION IN MILK POWDER PRODUCTION AND WAS COMPLETED IN OCTOBER 2016. THIS EXECUTIVE SUMMARY PROVIDES AN OVERVIEW TO ADVANCEMENTS MADE IN KEY TECHNOLOGIES FOR MILK POWDER PRODUCTION. MORE DETAILS CAN BE FOUND IN THE PROJECT PUBLIC DELIVERABLES[1] AND THE PRESENTATIONS HELD AT THE FINAL CONFERENCE[2] AND OF COURSE DIRECTLY FROM THE MENTIONED CONTACT PEOPLE.

PIETER DEBRAUWER

TNO, PROJECT COORDINATOR

[1]HTTP://WWW.ENTHALPY-FP7.EU/PUBLIC-DELIVERABLES/

[2]HTTP://WWW.ENTHALPY-FP7.EU/PRESENTATIONS-ENTHALPY-FINAL-CONFERENCE/

PROJECT OVERVIEW

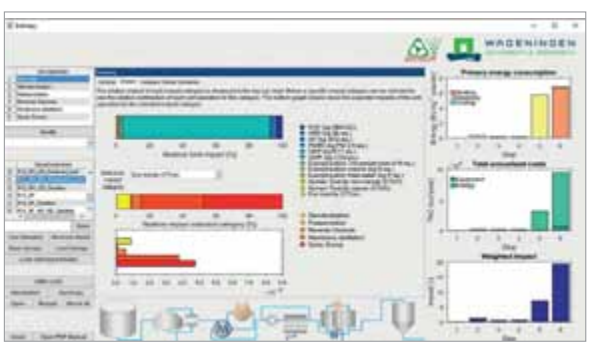
ENTHALPY was an EU-funded research and innovation project within the EC Seventh Framework Program to increase productivity and the competitive advantage of the European dairy industry, which currently consumes up to 8% of total energy generated in the EU.

The combined resulting technologies were demonstrated at pilot scale to reduce up to 45% of the energy and 15% of the water used in milk powder production. These groundbreaking innovations are now available for up-scaling, final validation and implementation in the dairy sector. Other industries employing spray drying such as the pharmaceutical and food processing industries e.g. for instant soups, drinks or flavors & spices, the bio-tech industry where algae or micro-organisms and their products need to be dried before further storage or processing can also benefit from ENTHALPY results. Besides spray-drying, revolutionary membrane separation and concentration technology as well as enzymatic cleaning of piping & process-reactors have been developed within an integrated approach to increase efficiency both for environmental and economic reasons. In-depth process modelling led to remarkable results backed up and verified by a meticulous life cycle analysis (LCA).

RESULTS ACHIEVED AND IMPACT

The commercially relevant results developed within ENTHALPY cover key technologies which were integrated to achieve significant savings in energy and water:

1. **Solar thermal energy and radio frequency pasteurization**
2. **Membranes for milk concentration and air recycling**
3. **Atomizer and spray technology**
4. **In-line monitoring systems for particle size and moisture**
5. **Enzymatic cleaning products**
6. **Analytical tools: CFD modelling & ENTHALPY app process design**



ENTHALPY successfully integrated innovative technologies in two pilot production plants where each process affects the performance of the subsequent one. Integration of heat and water flows between different processes leads to reductions over the whole production line. Process systems engineering evaluated and optimized all possible combinations of technologies in a systematic way. The main criteria for evaluation and optimization were operational costs, energy and water consumption and environmental impact.

RADIO FREQUENCY AND SOLAR POWER FOR MILK PRE-TREATMENT

To increase sustainability, there needs to be a shift to renewable resources (solar thermal) and decreased energy consumption (radio frequency heating).

Regarding renewable resources, in ENTHALPY, a solar thermal system working with overheated water was installed and successfully demonstrated in a pilot plant. It is now possible to sterilize milk just using solar heat and also pre-heat the air for drying. This was complemented with radiofrequency heating for pasteurization, which has additional advantages: it addresses the whole volume flow at once without the need to over-heat certain areas of the production process. This reduces fouling and thus the need for cleaning. At the same time, food properties (e.g. vitamins) are better preserved because partial over-heating is avoided.
Radio frequency is powered by electric energy, which can also come from renewable resources, further increasing sustainability.

These new facilities are now available for testing at IRTA.

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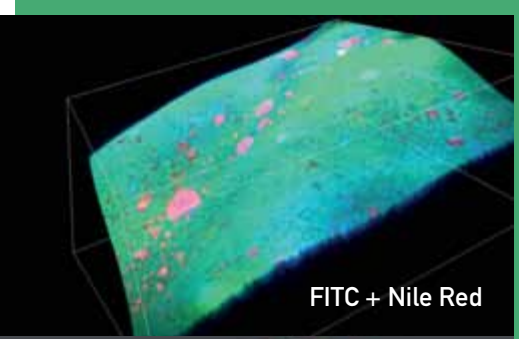

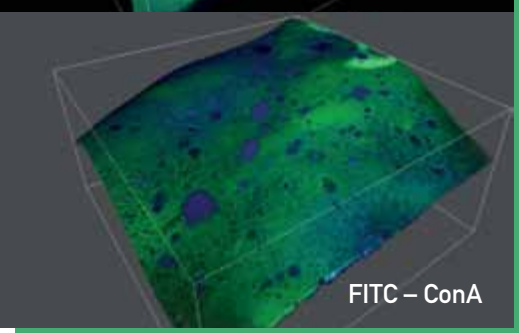

ENZYMATIC CLEANING

Regular cleaning in place (CIP) is important to ensure food safety but also causes downtime and additional cost as well as emissions of various cleaning agents.

A new method to model surface fouling was developed with application to many industries such as meat, fruit & vegetable processing or pharmaceutical industries. Together with novel detection methods of fouling composition, an enzymatic cleaning product was developed which achieved 91.5% of total fouling reduction in 45 minutes. The most valuable and crucial outcomes were patented, especially those related to new enzymatic formulas and a buffer for the removal of fouling. The effectiveness of this new formula has been demonstrated at pilot plant scale and significantly reduces downtime for cleaning and both water and energy consumption because of lower operating temperature. In contrary to conventional cleaning, the resulting effluent is biodegradable and there is no residual enzymatic activity in piping or contamination of product.

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MEMBRANES FOR MILK CONCENTRATION

Skimmed milk consists of only 9% of solid content, therefore a lot of water has to be removed in the drying process. Combined reverse osmosis and membrane distillation achieved 50% concentration.

For the concentration of milk before spray drying, membrane distillation was combined with reverse osmosis to replace energy-intensive steam-driven evaporation. Minimal energy input is required as water permeates through the membrane to concentrate the valuable solids. The membrane technology is also very gentle to the nutritious contents of the milk since milk-sugar is not caramelized, nor are proteins destroyed on hot surfaces. As a result skimmed milk with 9% solid content is concentrated to 13% using reverse osmosis and increased to 50% using membrane distillation.

A second membrane application removes moisture from hot spray drying exhaust air in a membrane contactor. With a theoretical energy reduction of 58%, on bench scale up to 48% were reached!

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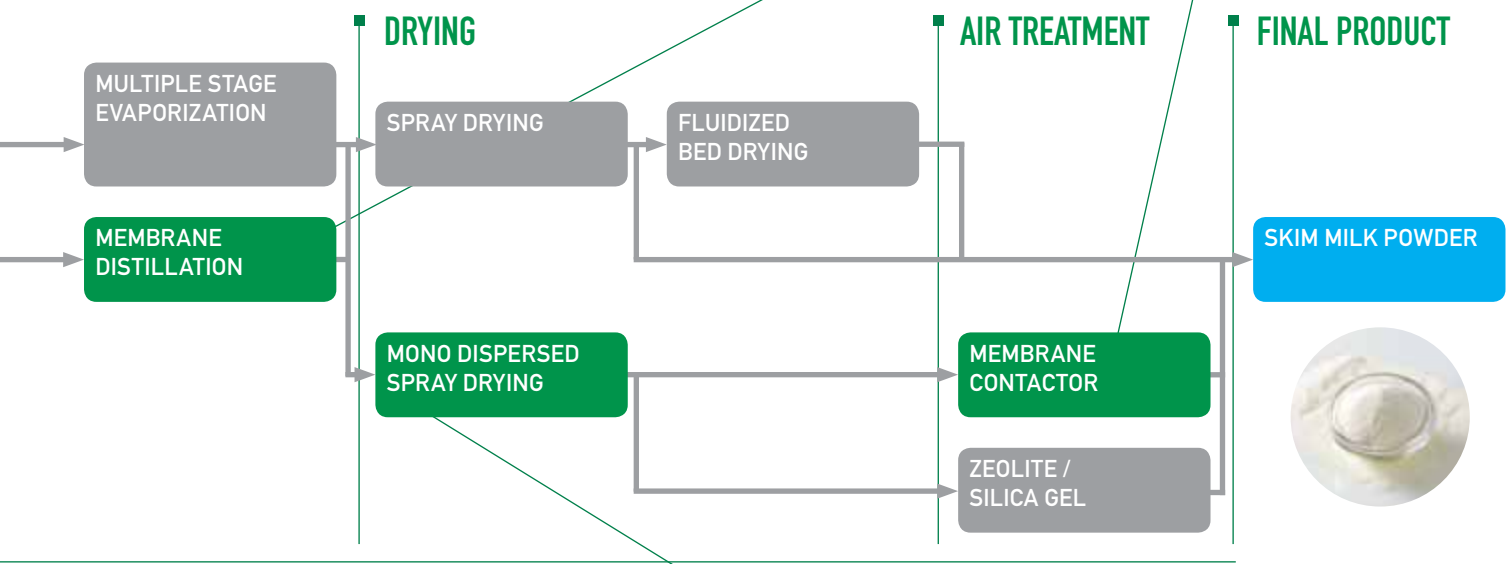

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LOW ENERGY SPRAY DRYING

Spray drying with the newly designed multi-nozzle, mono-disperse atomizer or "print-head" was taken to industrial pilot level. The atomizer can be combined with the membrane contactor to remove moisture so that hot air can be recycled to improve the overall spray dryer efficiency and performance.

Mono-disperse spray drying has two huge advantages: first, the resulting, uniformly sized droplets need less energy for drying, and second and even more important, no fine particles are produced. This means that hot air can be recycled after de-moisturizing in a membrane contactor. The atomizer works for liquids of various viscosities with ongoing trials to improve process stability and multiplying print-heads to scale up. The resulting uniform droplets have a very homogenous drying behavior and enable highly efficient fluid dynamics in the drying process. The exhaust air is de-moisturized by the membrane contactor and reused in the drying column in a closed cycle to keep heat loss to an absolute minimum.

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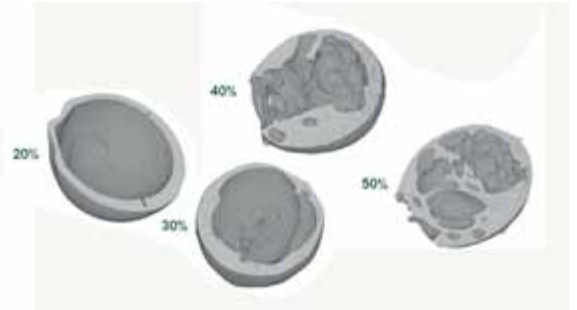
IN-LINE MONITORING OF PARTICLE SIZE DISTRIBUTION



A novel camera-based in-line digital image analyser (DIA) has been developed to determine the size and shape of particles in spray drying processes. With this the appearance of undesired agglomeration can be detected, results were found to agree well with off-line reference measurements. This can be complemented with X-ray tomography and other analysis methods for full characterization of spray dried powders.

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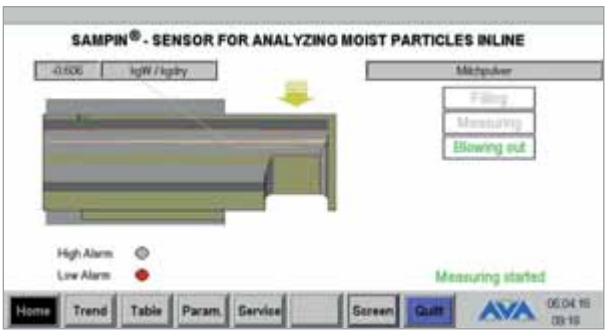
IN-LINE MONITORING OF MOISTURE CONTENT



Existing moisture measurement technology has been further developed for in line monitoring in spray dryers. The discharging mechanism was changed into a turning movement so that no compressed air infiltrates the process chamber, a cooling jacket was designed for use in high temperature conditions and the volume of the sample holder was reduced for smaller particle concentrations as found in spray drying process. Experiments with this new design led to calibration curve. A procedure was identified to eliminate the influence of changing bulk density, which would influence the measurement signal.

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DRYING TOWER MODEL

Reliable design of spray dryers was done by computational fluid dynamics (CFD). First a complex single droplet drying model was developed. However, due to high complexity of the mathematical description of heat, mass and momentum transfer between the phases in the CFD, it is necessary to use a simple equation of evaporation rate in order to minimize computation time. The developed CFD model can be used to simulate the spray drying process for different operational conditions (air temperature, spray mass flow rate). Simulation results were analysed in the frame of a stepwise approach (from simple settings to real process conditions).

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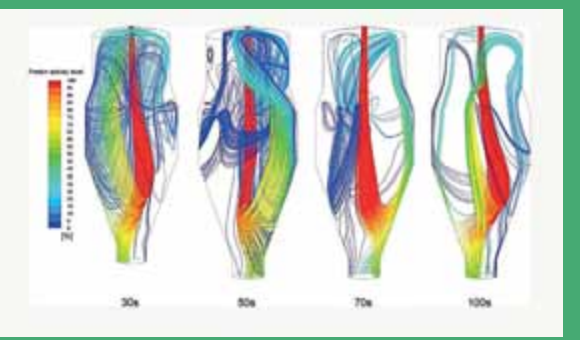
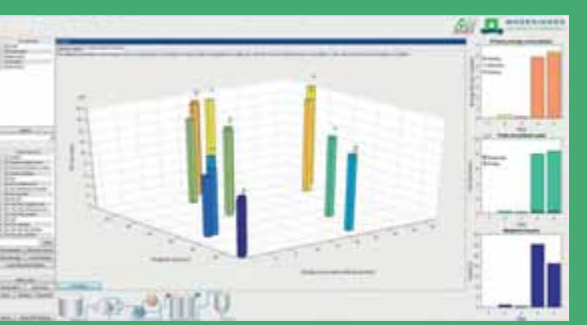


PROCESS SIMULATION TOOL (ENTHALPY-APP)



The ENTHALPY Graphical User Interface (GUI) application was made to showcase aspects of the simulation tool that was developed by the Biobased Chemistry and Technology (BCT) group of Wageningen University & Research (WUR). It can be used to perform quick simulations of different milk powder production processes and analyse these with respect to energy consumption, costs, and environmental impact comparing different stored scenarios. Current models are based on previously done literature research and experimental data.

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TECHNOLOGY INTEGRATION AND DEMONSTRATION

The ENTHALPY project used a holistic view of on the entire milk powder production process from theoretical calculations in process engineering, simulations and life cycle analysis, and finally validated the resulting technologies and processes in two pilot demonstration plants.

At the demonstration facilities of IRTA in Monells, Spain, a solar thermal system was installed working with superheated water to supply heat to ultra-high temperature processes and the spray drying tower. Solar thermal installations were supplemented with radiofrequency (RF) heating for milk pasteurization and sterilization, which abolishes overheating and thus improves product quality. Running on electricity, radiofrequency heating can be powered by renewable sources. Thus, combining these two technologies makes it possible to avoid fossil fuels in milk and other similar food and pharmaceutical processing plants. Additionally, the enzymatic cleaning process was integrated and validated in this pilot plant.

The pilot plant is now available for testing other food processing applications:

- **120 m² of solar thermal panels working with overheated water up to 160°C**
- **Supplying energy to a spray drying tower and ultra-high temperature heating equipment**
- **Radiofrequency heating for all types of food**

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The pilot plant at Bodec in Helmond, The Netherlands, was used to validate technological advances in spray drying technologies. In this pilot plant it could be demonstrated, that existing spray dryers can be retrofitted with the multi-nozzle print head for spraying mono-disperse droplets developed in ENTHALPY. Trials are currently continuing with tower and frequency modifications to improve process stability and powder production. This demonstration setup is now available also to others to test the monodisperse atomizer system and to evaluate spray drying of powders.

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ENTHALPY

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