## 1. MicroMilk Final Report - Executive summary

The MicroMilk project involved the development of a novel microwave heating process to facilitate cost-effective, energy efficient, easy to clean and flexible processing of a wide range of different milk variants, including those with high viscosities with minimum start-up and shut-down and minimal surface fouling. Currently, most common technology is indirect heating by using plate heat exchangers. This requires a cleaning in place system to be used quite often because of milk layers burning at the surfaces of the heat exchangers and other equipment, leading to increased shut-down time. The milk industry aims at reducing the cleaning time of milk processing plants to increase the production time while saving water and energy.

Accordingly, the MicroMilk project aims were:

To create an electro-thermal model of microwave cavity to enable controlled and uniform heating; To design, simulate, optimize and develop a demo-system; To enhance the microbiological, nutritional and organoleptic quality and the shelf life of milk; To reduce the cleaning time and minimise the contamination sources of milk via equipment; To comply with HACCP and GMP regulations; and to decrease cost of overall milk treatment.

Within this project a 400 L/h novel microwave milk pasteurization prototype was successfully developed and validated. Benchmark comparisons between thermal processing via conventional indirect heating and microwave heating were conducted using reference methods of analysis to evaluate key quality parameters. For this purpose, the cavity reactor was integrated to an existing pasteurisation system, including newly developed full process automation and control.

Within the prototype system, relationships between temperature rise (dT) and milk matrix composition were established. It was observed that at constant flow rate, dT increases linearly with dry matter content. Further, temperature rise was reached 3 times quicker with microwaves than with conventional indirect heating (under equivalent flow rates and retention time conditions). Non-significant differences between microwave pasteurisation and indirect pasteurisation of milk in terms of physico-chemical (e.g. furosine and HMF formation), microbiological, nutritional (vitamin B1) and sensory properties (colour, taste) were observed.

Based on performance results and end-user requirements, the MicroMilk cavity reactor was further optimised and extended to an industrial concept at a scale of 1000 L/h. Optimisation was achieved in cooperation with MicroMilk partners by using the Quality function deployment (QFD) approach, followed by CAD Modelling, and field simulations to predict the propagation of the electric field inside the cavity. The developed system replaces the conventional heating unit (plate heat exchanger), and is integrated into a standard milk pasteurization plant, including CIP cleaning and full energy recovery.