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Final Publishable Summary

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Executive summary

The MicroMilk project (Grant Agreement Number: 262603) funded by the R4SME programme (call identifier: FP7-SME-2010-1) delivered high quality science and technology development. MicroMilk involved the RTD of a novel process to facilitate cost-effective, energy efficient and flexible processing of a wide range of different milk variants, including those with high viscosities with minimum start-up and shut-down, minimal surface fouling and therefore less cleaning efforts and water being wasted. A novel continuous microwave milk pasteurization system was successfully developed and validated. The results showed that heating times are 3 times shorter than state of the art indirect heating. Both the indirect and microwave heating result in comparable microbiological, physico-chemical and sensory quality (experimental & commercial). This confirmed that microwave pasteurisation is suited for the commercial production and distribution of drinking milk. The developed cavity reactor was integrated into a standard milk pasteurization plant, including CIP cleaning and full energy recovery. An industrial scale unit has been designed and specified.

Further demonstration at industrial sites to confirm long-term performance, operational costs and economic viability were undertaken to enable the research results from MicroMilk to be translated into commercial reality. These include industrialisation of manufacturing processes to enable economies of scale to be achieved. Long term tests of the 915 MHz system showed the satisfying performance of the system under industrial conditions. The consortium has identified a number of market opportunities and is keen to bring this development into an industrial stage.

Project context and the main objectives

The MicroMilk project (Grant Agreement Number: 262603) funded by the R4SME programme (call identifier: FP7-SME-2010- 1) delivered high quality science and technology development. MicroMilk involved the RTD of a novel process to facilitate cost-effective, energy efficient 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. To enable these research results to be translated into commercial reality there is a need to industrialise the prototype technology, verify its commercial viability with a range of products and to ensure target market acceptance.

As part of the dissemination activities in this prior RTD project, a number of market opportunities were identified and several potential customers registered interest in purchasing the industrialized technology. For these high quality RTD project results to be translated into a commercially viable product there was a need to industrialise the process and to demonstrate it in various applications at a larger industrially representative scale to potential commercial customers. Therefore support was requested under the FP7-SME-2013 Activity 2.3: Demonstration, to enable market exploitation of these prior RTD results. The R4SME MicroMilk Project successfully developed and validated a 400 L/h novel microwave milk pasteurization prototype (single mode reactor, single magnetron - SMSM) and extended this approach to specify an industrial concept to replace the conventional heating unit (plate heat exchanger) at a scale of 1000 L/h, integrated into a standard milk pasteurization plant, including CIP cleaning and full energy recovery. The developed (extended) concept consists of single mode reactor splitted into more than on sections and each section being fed by only one magnetron. Based on number of magnetrons and sections of single mode cavity being more than one, the approach is referred to as a SMMM (Single Mode Multi Magnetron) design. Within the prototype system, with a maximum power of 6 kW, relationships between temperate rise (dT) and milk matrix composition were established. Overall, dT values ranging from 8.5 to 10°K could be reached at flow rates of 400 l/h. At constant flow rate, dT increases linearly with dry matter content. In current prototype system temperature rise was reached 3 times quicker with microwaves than with conventional indirect heating (under equivalent flow rates and retention time conditions). Accordingly, it can be anticipated that the developed industrial scale SMMM concept (1000 L/h) will reach target pasteurization temperatures within 3 seconds, 4 times quicker than comparable conventional pasteurization units (13 s). The novel MicroMilk system was able to provide microbial stability comparable to conventionally-pasteurized milk (indirect heating) and to enhance nutritional quality and taste of milk. Further, it was identified that microwave pasteurization has major advantages for special products containing high amount of solids, which can be effectively heated in a shorter time while minimizing surface fouling of the equipment, thus reducing shut-off time, cleaning efforts and water usage. This technical approach has been identified as being highly suited and more appropriate than existing state of the art approaches for small and medium scale dairies; there are over 1 million holdings in EU27 producing 138.8 million litres pa of milk (data from 2011)1, at present they typically have to either sell it to larger dairies at marginal cost (27ppl)2 or have to run expensive continuous thermal process. Only 30.4 million tonnes out of total 138.8 million tonnes is being processed as drinking milk and the rest is converted in some other products like cheese, butter, milk powder, condensed milk, fermented products or cream by ca. 310,000 producers, adding value to the supply chain and generating over 4 million Jobs in Europe3.

The main objectives of the MicroMilk DEMO project were:

1. To ensure effective management of the consortium; the management and coordination of the project with the EC and the overall management of the scientific undertakings. Ensure all milestones and deliverables are met on time and to budget.(WP1)
2. To design an industrial cellular manufacturing process to enable the production of robust integrated MicroMilk units. To demonstrate the production process with at least two microwave pasteurization units designed to addressed identified market needs: 1) a unit with a throughput of 2000 L/h to be used in dairy factory for flexible thermal treatment of special dairy products in short runs (plate heat exchanger) and 2) a unit with a throughput of 1000+/- 250 L/h for high-solid content dairy and other food products with particles for long runs (tubular system) for evaluation in WP3. Simplify and standardize components by establishing value engineering procedures (WP2)
3. To monitor the operation of the two units produced in WP2 which represent two different industrial applications for a period of over six months continuous operation. Key performance parameters to be monitored will include: time, temperature, pressure, flow rate, power consumption, time-temperature heating profile and product quality (microbial, chemical and organoleptic analyses). To evaluate cleaning performance, required shut-down times and estimate operational costs as compare to SoA approaches. After six months the two units will examined for deterioration of cavity material and fouling formation. (WP3)
4. To develop economically sustainable business exploitation strategy for the post-project market replication of the results. To assess financial risks and elaborate a business plan (WP4)
5. To prepare training methodologies in the operation of the process. To ensure full and complete transfer of knowledge from the RTD performer to the SME partners. To present the industrial units technically validated in WP3 to over sixty industry representatives. (WP5).
6. To ensure continued IP protection for the benefit of the SME partners. To disseminate protected IP which will be undertaken to enable maximum commercialization of the results post-project, dissemination actions to include; five publications or conference proceedings and, presentations to at least two European industry trade shows. (WP6)

Main S & T results/foregrounds

Within the first reporting period the design of microwave cavities and piping inside cavities has been successfully optimized in terms of energy and manufacturing cost efficiency. The design principle is based on the results of the R4SME MicroMilk project and was transferred to the selected applications after further optimization. The optimization was carried out in order to increase the efficiency of energy conversion of electrical energy from microwaves into thermal energy in the dairy product. Subject to the required technical parameters and facilities at end user locations (e.g. max. power supply, cooling system and cleaning in place peripheral system), appropriate peripheral units, sensors, safety alarms and connections were considered in the design process. The optimization results obtained by the RTD performer Fraunhofer were communicated to the SME partners and the design principles were transferred to the manufacturing of the cavities and the microwave generators. Based on the gained experience during the manufacturing process first projections about the costs and the sales prices were made by SME partners which will be further refined during the project.

Intensive communication between project partners in several management and technical meetings and also informal bilateral meetings ensured the progression towards the objectives within the project. One of the outcomes of the meetings was a risk register where issues that challenge the achievement of project deliverables and milestones, both technical and economic, were recorded and mitigation strategies were defined. The IPR strategy was discusses between SME partners. It was decided to go on with the strategy developed for the project MicroMilk. This strategy includes patenting the developed microwave heating technology for dairy products. All plans regarding use and dissemination of the technology are compiled in a PUD. First dissemination activities were reported in the dissemination protocols. The dissemination activities included a press release in English and German language, articles in dairy related journals and the presentation of the project at two scientific conferences. Furthermore the project website has been uploaded (http://www.micromilk.eu/) where information about the MicroMilk Demo project and the previous project MicroMilk is provided to a wider public. The organization of the presentation of the technology at two exhibitions (Industrial Processing 2014, AnugaFoodTec 2015) is on-going.

The 2,45 GHz microwave developed in the MicroMilk DEMO project should replace a conventional plate heat exchanger applied for heating in the milk pasteurisation process. The pasteurization system consists a regeneration zone for heat recovery and a heating zone for heating the milk to the desired pasteurisation temperature. Two different configurations for a 2,45 GHz waveguide (=cavity) were designed based on the results of the previous project MicroMilk, constructed, manufactured and tested under lab-conditions. In order to verify the performance of the system flow trials with water were performed. The pilot scale set-up was tested at various flow-rates and temperatures of the liquid. The facility didn’t show any incidences regarding the working temperature or pressure in the tested range. No occupational safety issues regarding microwave leakage were found.

In order to compare the two different configurations of the 2,45 GHz fast and easily a Vector Network Analyser was applied. The Vector Network Analyser is a kind of network parameters measuring instrument. The complex scattering parameters of single-/multi-port networks can be directly measured by the vector network analyser. The scattering parameters quantify how radio frequency (RF) energy propagates through a single-/multi-port network. They allow us to accurately describe the properties of incredibly complicated networks as simple "black boxes". For an RF signal incident on one port, some fraction of the signal bounces back out of that port, some of it scatters and exits other ports (and is perhaps even amplified), and some of it disappears as heat or even electromagnetic radiation. The Vector network analyser measures the reflection coefficient by emitting microwaves at low power and measures the reflected power. The reflected power is the electrical power which is not absorbed by the liquid and will consequently not contribute to the temperature increase in the liquid.

The decision about the final 2,45 GHz industrial design was made based on the results of the Vector Network Analyser.

The 915 MHz multimode cavity should replace a conventional tubular heat exchanger for preheating dairy concentrates before spray drying. The mode spectrum of the cavity was determined by means of simulation in order to optimize the design. The principles of the program are as following:

- The number of modes that exist in the cavity are given by:

$$\frac{4 * eps}{(\frac{c}{f_1})^2} < (\frac{m}{a})^2 + (\frac{n}{b})^2 + (\frac{p}{d})^2 < \frac{4 * eps}{(\frac{c}{f_2})^2}$$

- a, b, d are the dimensions of the cavity along the x, y and z axes .
- m, n and p are integers corresponding to the number of half wavelengths of quasi-sinusoidal variation of the field along the x, y and z axes respectively
- while f_1 and f_2 are the upper and lower limit for the working frequency of the magnetron.
- Each combination of m n p, which can fulfil this equation, exists in the cavity theoretically.

Electrical field distribution inside the cavity was determined by means of simulation. The higher the number of modes, the more homogeneous the energy distributes. The optimal piping configuration was found by numerical simulation by means of CST Microwave Studio. In order to narrow down the optimizing parameters reasonable pipe diameters were preselected.

The control system is based on the control system developed for the MicroMilk project. It has the following general features:

- Automatic mode in which the operator gives the desired temperature and the control system calculates the required total delta T.
- PID loop between delta T within the microwave cavity and the magnetron. The output power of the magnetron should be inversely proportional to the delta T.
- Automatic shutdown of magnetron if there is no flow indicated
- Cooling water temperature from the magnetron will be displayed. There should be a warning massage in case the temperatures are outside a range specified during set-up of the system

Based on the optimized designs the two demonstrators (2,45 GHz and 915 MHz) were constructed, and manufactured. The 915 MHz demonstrator was shipped to Schwarzwaldmilch installed, commissioned and tested under real world conditions.

Key performance parameters to be monitored have been identified as including: time, temperature, pressure, flow rate, power consumption, time-temperature heating profile and product quality (microbial, chemical and organoleptic analyses). Physical parameters like temperatures and pressures were recorded and time profiles of all parameters were extracted from the data logger. Product quality was assessed after each trial.

Testing of the 915 MHz microwave system showed that it takes approximately 6 min until a stable temperature is reached after the microwave generator was switched on. Based on logged data the efficiency of conversion of microwave power to thermal power in the product to be heated was calculated. Tests were conducted with Quark 35. It was determined that the reflected power in the quark trials was significantly lower than in the water trials conducted for testing under lab conditions. A lower reflected power indicates that more microwave power is absorbed by the fluid. The system was operated up to two days without interruption. Minor fouling could be found, which is not critical for operation. Also the pressure drop in the system stayed constant during testing.During demonstration phase the robustness of operation in the industrial environment was enhanced and the fluctuations of the outlet temperature were significantly reduced to meet the requirements of the end-user.

During the trial, samples were taken and later analyzed in the laboratory. The particle size, dry matter content and protein content were measured. Microbial analyses were conducted with the end-product (powder). Quark after heating was a homogeneous product with normal fluctuations in protein content and dry matter. Quark is like fresh cheese a microgel suspension with different sized protein aggregates in a liquid phase. Water content of the produced powder was about 6 % and protein content about 37 % as expected. The results of the colony forming units of total plate count and aerophilic spore formers were low. This was expected cause of the low ph with of 4.62 and the heat sensitive starter cultures.

The economic performance of the 915 MHz system was further analysed:
Cleaning performance: The microwave was cleaned by routine CIP-procedures of Schwarzwaldmilch. No abnormalities were detected
Shut down times: The shut-down and start-up procedure of the microwave system is by far faster than for conventional steam-heated system. The microwave is ready for operation or switched off within minutes. Almost no heating-up or cooling-down times are needed. The operation time between shut-downs is longer than for conventional systems. We anticipate the doubling of the operating time.
Payback period: Calculations showed that for high profit margin products (7-23 %) payback periods of less than a half year can be realized. For medium profit margin product (2,5 to 5,5 %) payback periods of less than 2 years can be realized.

The 2,45 GHz microwave system was tested in the van't Riet workshop. Tests were conducted with water. The efficiency of conversion of microwave power to thermal power was significantly lower than expected. Measures to improve the efficiency were conducted. It was found that under certain process conditions the efficiency of conversion of microwave power to thermal power was close to 100 %. Tests are ongoing in order to improve the robustness and reliability of the system.


A HACCP analysis regarding the microwave heating step was conducted for both applications:
Preheating of concentrates before spry drying:

Potential hazard	Preventive Measure	Critical Control Point	Critical limits	Monitoring procedures and frequency	Corrective action	Record	Verification
Microbial contamination build-up	Proper sanitation and GMPs	Cleaning and sanitation of microwave	As per established cleaning and sanitation procedures	Where long runs are necessary operate microwave at temperatures above max. growth temperature of thermophilic microorganisms	Re-clean	Cleaning and sanitation record	Inspection of machine weekly by in-charge to ensure cleaning. Periodic specialist examination and maintenance of plant by manufacturers.
Splinters from broken microwave transparent tube	Detect broken tube	Product in-Flow and out-Flow	Deviation of product in- and out-flow of more than 10 %	Product in- and out-flow is monitored continuously. The microwave stops automatically if deviation is too	Replace broken tube	Process record by microwave control system	Inspection machine weekly by in-charge. Periodic specialist examination and maintenance of

				high.			plant by manufacturers.

Pasteurisation of milk:

Potential hazard	Preventive Measure	Critical Control Point	Critical limits	Monitoring procedures and frequency	Corrective action	Record	Verification
Survival of pathogenic microorganisms	Operation according to conformed sanitizing, start, processing and stop procedure	Holding time and temperature	≥ 76 °C ≥ 15 s	Check temperature setting and records at start and end of each batch	Reprocess milk if necessary Fix faults	Data logger	- Audits by dairy's quality assurance department of the processing plants, suppliers of packaging material and chilling and transport sections - Reviewing and discussing the monitoring results of every processing plant at intervals of 4-6 weeks. This would include such results as of the testing for recontamination, the testing at the "use-by" date and other inspection tests - Review and analysis of complaints at half-year intervals - Results of public health inspection - Audits by external agencies of quality assurance system - Results of market research
	Automatic safety system to prevent too low temperatures	Diversion valve	Diversion at ≤ 76 °C	Check diversion and automatic stop every 2 weeks. Check diversion valve before every batch		Data logger	
	Extra cleaning in case of more than 3 days between processing runs Dismantling and inspection every 2 years Flow control and assurance	Temperature calibration	Thermocouple to be within ± 0,5 °C	Calibrate temperature and pressure measuring devices every 6 months	Repair or replace sensors and recalibrate before use	Calibration record	
Microbial contamination	Restrict running to 6 h	Cleaning and sanitation of microwave and related subsystems	Refer to cleaning and sanitation procedures	Ensure that the microwave has been cleaned and sanitized before use Test for corrosion cracks Test and calibrate pressure difference control	Re-clean and sanitize Analyze origin of deviation and improve preventive maintenance	Cleaning and sanitation record Deviation and corrective action record	

In parallel with the design, construction and manufacturing activities training manuals and a training video were prepared. The documents were prepared in a format that allows those that have been trained to readily transfer the knowledge and methodology onto others. The training manuals were designed on the basis of “train the trainers”. Each trained individual will be able to transfer knowledge on the use of the microwave heating system to their customers. Different training documents were developed to appropriate to varying levels of technical education, skills and needs. The training documents will also facilitate feedback so that lessons learnt by practitioners can be feedback to enable iterative enhancement of the training modules. The pictorial based training documents were also designed to enable remote learning via the internal project webpage. The documents were prepared in English and German in a format that enables ready translation into other European languages and with a high pictorial content to enable others to understand the key operating principals of microwave heating system. The training video was developed in order to give an introduction into the benefits of the microwave system, basic knowledge about the physics behind microwave heating and basic functions of the microwave system. The training video serves as an interconnection between the training manuals. While in the training manuals the different compartments of the microwave system are described in detail, the training video gives an overview over the whole system. The training video as an introduction to the MIcroMilk Microwave heating system addresses to system operators and maintenance personnel as well as to supervisors and was prepared in English and in German.

The Exploitation Manager, Piet Verburg (van’t Riet) was responsible for ensuring full and total transfer of the project results from Fraunhofer to the SME participants so that they are able to integrate the results into their individual businesses and exploit the result post-projects. Initial technology transfer sessions were undertaken at Fraunhofer followed by subsequent follow up sessions at the offices of each of the SME participants. Knowledge transfer was conducted during formal management meetings as well as in technical meetings and remote trainings via phone or emails with single SME participants or with several SME partners. In the following the knowledge transfer events and the contents are described in brief.

Description of the potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and the exploitation of results

The MicroMilk-DEMO project aimed to bridge the gap between research and market; to enable high quality EC funded RTD results to be translated into commercial exploitation by the SME participants from the MicroMilk R4SME project. This was through the following stages; industrial scale production of the microwave cavity reactors integrated to flow pasteurization units, including process control, validation at of microwave pasteurization process on selected applications at two industrial locations of economic, technical and viability, including financial risks and, to enable widespread dissemination to potential commercial clients to facilitate post-project market replication.

The MicroMilk DEMO project progressed beyond the State of the Art (SoA). It built on, integrated and demonstrated prior high quality Research and Technology Development that has been undertaken in the fields of microwave pasteurization. Through a process of training and knowledge transfer the project results were transferred from the RTD performer to the SMEs to enable them to commercially benefit and improve their competitive position**.** The work done in this project enabled the consortium to overcome the limitations of currently available technology in the application of pasteurization systems via indirect heating sources. The technological expertise came from both the RTD performers and from the SME participants. The MicroMilk approach offers advantages over SoA approaches; it provides a homogeneous flash heating system, minimized formation of layers on equipment surfaces and thus less shut-off times, cleaning efforts and water consumption. It enables the recovery of energy by integrating the microwave cavity to the regeneration area of current pasteurization plants; this proposes an alternative for continuous heating of products with high-solids contents, which are currently difficult to handle in pipes. The latter will result in an overall efficiency increase of several production lines as well as overall reduction of operational costs in dairy and food processing plants.

<u>**Potential impact on customers from food industry**</u>

The main need of food producers is the reduction of fouling costs. Fouling costs are substantial in food industry and the reduction in these costs would be a desirable contribution to profitability and competiveness of food manufacturers. Fouling causes high financial constraints to the food industry. For example in the USA the total costs for fouling have been estimated to be $7 billion 1. The economic impact of fouling is so severe that the total fouling costs correspond to about 0,25 % of the gross national product of a developed country such as the USA 2. In the dairy industry fouling accounts for about 80 % of all operating costs3.

In detail fouling causes economic…

- Equipment downtime for additional cleaning, maintenance and repair with the effect of loss of production and profit of food manufacturers reducing their competiveness
- Increased capital costs: Additional processing equipment (oversized equipment: 70-80 5 30-50 % assigned to fouling, to extend operation time) and cleaning equipment, extra space, increased transport and installation costs
- Costs for effluent treatment
- Loss of product

…and environmental cost related consequence.

- Additional energy consumption and related costs during operation to compensate for reduction in process efficiency, energy losses due to the decrease in thermal efficiency and increase in pressure drop
- Increased required maintenance including water intensive cleaning and use of antifoulants
- Increased use of chemicals for cleaning
- Environmental impact due to increased energy demand during operation, increased water demand during cleaning and higher effluent discharge

The MicroMilk system is the foundation to bring to the market a heating system which will enable our customers to increase operation time and increase process efficiency compared to conventional heating systems based on heat exchange surfaces being susceptible to fouling. We anticipate at least the doubling of the average operation time between two cleaning cycles from 24 h to 48 h. With our system food manufacturers will be able to half the down time costs related to heater cleaning by increasing the operation time and reducing the time for cleaning and related shut-down and start-up procedures by 50 %. With energy costs on the rise, increasing process efficiency will directly impact on the business of our customers. Most

[1] (HM Müller-Steinhagen. 2000. Handbook of Heat exchanger fouling: Mitigation and Cleaning Technologies. Essen, Rugby: Publico Publications, Institutions of Chemical Engineers)

[2] (HM Müller-Steinhagen, MR Malayeri, AP Watkinson, 2005. Fouling of heat exchangers – new approaches to solve an old problem. Heat Transfer Engineering 26:1-4).

[3] (B Bansal, XD Chen. 2006. A critical review of milk fouling in heat exchangers. Comprehensive Reviews in Food Science and Food safety 5:27-33)

food and drink manufactures have small margins and are only able to maintain their businesses if they can manage operational cost and their resources adequately. The MicroMilk system will significantly increase the revenues and profits of food manufacturers and enhance competiveness. We will enable food manufacturers to produce just-in-time by providing a heating system with remarkable short start-up time. The system will be ready within 10 min after switching on, because microwave radiation selectively heats up the food but no pipes, housings or other big masses of metal like in conventional heat exchangers.

Further needs of potential customers were identified by direct contact (e.g. at AnugaFoodTech 2015):
Develop foods with novel quality characteristics: Microwaves heat fluids volumetrically that means the whole volume is heated evenly including emulsified phases and particles. Microwave heating is not limited by the different heating-up properties of different phases and particles like conventional heating. Particles and even their centers heat-up as fast as the surrounding liquid enabling the reduction of the overall processing time of the food and in the consumer perception they are regarded as fresher and more valuable than conventionally heated products.
Lower water consumption: Especially in regions suffering from water scarcity but also in regions with high water and effluent discharge fees the reduction of water consumption is of high interest for food manufacturers. The MicroMilk technology increases the operating time between cleaning cycle and consequently the number of cleaning cycles necessary. Cleaning is the number one water consumer in food processing. Furthermore for microwave heating no intermediate energy carrier like steam is needed like in conventional heat exchangers, but microwave radiation is directly converted to heat inside the food. For steam production high quality water is needed, which becomes obsolete when using a microwave heater.
Reduced non-renewable energy consumption: Food companies willing to improve their image or acting under public pressure need to reduce the consumption of energy from non-renewable sources. The microwave heater works with an electric power source. The electric power source may be from solar power or other renewable energy sources like wind instead of a gas fueled steam generator required for conventional heat exchanger systems.
Just-in-time production: Food manufacturers desire a flexible just-in-time production. The MicroMilk system shows a remarkably fats start-up and shut down behavior. It takes less than 10 min to get it to stand-by mode after a complete shut-down. And less than 2 min until the product leaves the microwave heater at the desired temperature when power is switched on in stand-by mode.
High flexibility in terms of flow rates and temperatures: Food manufactures wish to be flexible in terms of food flow rates and outlet temperatures for different foods. With conventional heaters those values are fixed by the size of the heat exchanger surface and the given steam pressure. The MicroMilk heater is highly flexible by just increasing or decreasing the required microwave power to heat the food at a desired flow rate to a desired temperature.
Avoid cross-contamination: Food manufacturers need to avoid cross-contaminations between different foods whether due to health reasons (e.g. transfer of allergens) or religious reasons (e.g. kosher production). When using steam or condensate as energy transfer medium it cannot be completely avoided that components from one food are transferred to the steam or condensate and from there are transferred to another food. Using the MicroMilk system there will be no risk of cross-contamination because there is no heat transfer medium like steam or condensate. The microwave radiation is converted to heat directly in the food.

As an example for the individual further economic benefits of food manufacturers we calculated the economic benefits due to increased overall process efficiency for the dairy Schwarzwaldmilch where the demonstrator developed in the project MicroMilk DEMO was tested. In the case of Schwarzwaldmilch the main economic benefit beside reduction of downtime costs is the increase of overall process efficiency caused by preheating the spray tower feed before the actual drying process. The spray tower feed was heated from approximately 30 ° to about 50 °C by the MicroMilk demonstrator. About 23,5 kW electrical power were required for this temperature increase (electricity costs: 3,2 cents/kWh → 75,2 cents/h) . As a result the amount of water evaporated in the spray tower per hour increased by 44 kg. This is equivalent to energy savings of 27,6 kWh in the spray tower. The spray tower is heated with steam. The required steam decreases by 35,9 kg per h at a steam pressure of MicroMilk 8 bar (not considering losses). The production of 35,9 kg of saturated steam costs about 2,1 €. The savings per hour are 1,35 €. W, 32,4 € per 24 h or 9500 € per year considering an uptime of about 80 %. Beside the savings due to reduced energy demand the dairy powder production was increased from 125 kg/h to 136 kg/h being an increase of 8,8 %.

The economic impact of **product quality benefits resulting in manufacturer sales price increase and growth in market share** have to be assed individually by each customer. The following quality benefits were identified resulting in foods with innovative characteristics:

- Increased "freshness" due to shorter heating up time of food products
- Intact particulates in food (e.g. nuts or fruit pieces in ice cream)

Innovative food products differentiate the own product pallet from competitors', generate new markets and create value in the competitive food market. Leading food manufacturing companies like Nestlé point out that innovation is the major booster for market growth worldwide.[4]

[4] nestle.com/media/pressreleases/allpressreleases/full-year-results-2014

Potential impact on members of the consortium

For the consortium members it is important to regularly renew the offerings to our customers in order to follow our long term business strategies to maintain the size of our companies, grow organically and strengthen our IP ownership. For this purpose we intend to diversify our range of products, offer new products to our customers, open new client segments and gain lead customers. To sell the microwave technology will be a radical renewal of our range of products, increase the turnover and create jobs in our companies. A draft commercialization plan can be found below.

<u>Dissemination and exploitation of results</u>

Stake holders

We identified the following stake holders of the MicroMilk technology that are key to get involved for making a successful commercial exploitation: Our primary key stake holders are lead users where we demonstrate our technology and identify and eliminate minor weaknesses of system that only occur in real world application. The lead users will be a reference and example for the successful application of our technology. By disseminating the outcomes of the demonstration tests we will boost the interest of potential customers and facilitate future sales. First target of our dissemination activities are managers in decision making positions in the food processing industry who make the decision for or against the purchase of processing equipment. Since the food processing industry is very price sensitive the managers will be primary informed about the economic benefits of the MicroMilk technology. To maintain food safety is crucial for food processors, hence the decision of managers is influenced by experts in the fields of food quality and food processing. We will provide information to the food professional community from demonstration trials about food quality and technical performance to influence the opinion of quality and processing experts positively.

The following table shows the main dissemination activities in the MicroMilk DEMO project:

No	Type of activities	Main leader	Title	Date	Place	Type of audience	Size of audience	Countries addressed
1	Poster at Scientific Conference	UHOH	“Dairy Conferences 2013”	16-17.09.2013	Stuttgart	Academics, Industry	100	Europewide
2	Press Release of MicroMilk DEMO at Fraunhofer website	FhG	„Gentle pasteurization of milk – with microwaves“	online from 30th October 2013	Fraunhofer Website	General Public	>10000	World wide
3	Press Release of MicroMilk DEMO	FhG	„Gentle pasteurization of milk – with microwaves“	19.11.2013	DailyMe.com	General Public	>10000	World wide
4	Press Release of MicroMilk DEMO	FhG	„Gentle pasteurization of milk – with microwaves“	26.11.2013	RF Global Net	General Public	>10000	World wide
5	Press Release of MicroMilk DEMO	FhG	„Gentle pasteurization of milk – with microwaves“	20.01.2014	Science 2.0	General Public	>10000	World wide
6	General overview of MicroMilk DEMO	Van’t Riet	“Pasteurisatie via microgolven”	22.01.2014	ZuvielZicht	General Public	>1000	Netherland
7	Poster at Scientific Conference	FhG	Development and validation of a novel microwave heating system for special milk processing applications	26-27.02.2014	Freising	Academics, Industry	100	Germany
8	Oral presentation at chamber of industry and commerce (IHK Südlicher Oberrhein)	S-Milch	MicroMilk – Erfahrungen mit einem KMU-Projekt	19.11.2013	Freiburg	Academics, Industry	100	Germany
9	Press Release of MicroMilk DEMO	DanTech	MicroMilk Demo – Press Release	11.10.2013	DanTech Website	General Public	>10000	World wide
10	Presentation of MicroMilk DEMO on website of Dantech	DanTech	Nutritional and shelf stable milk by novel microwave processing	Updated 12.09.2014	www.dantechuk.com	General Public	>10000	World wide
11	Exhibition	Van’t Riet	Industrial Processing	30.09.-03.10.2014	Utrecht	General public, Potential customers	>1000	Europe wide
12	Exhibition	Van Riet	Anuga FoodTech Project overview (Poster); Peripheral units	24.03-27.03.2015	Cologne	General public, Potential customers	>10000	World wide
13	Exhibition	DanTech	Anuga FoodTech MicroMilk system	24.03-27.03.2015	Cologne	General public, Potential customers	>10000	World wide
14	Presentation of MicroMilk DEMO on	S-Milch	MicroMilk	End of September	S-Milch Website	General public	>10000	World wide

	website of S-Milch			2014				
15	Business Meeting	DanTech	Business Meeting with MKS	31.10.2014	Liverpool	Industry	3	Germany
16	Leaflet on Roadshow	Malthe Winje	MicroMilk	23.-24.10.2014	Oslo	Industry	>1000	Norway
17	Presentation of MicroMilk DEMO on website of Malthe Winje	Malthe Winje	MicroMilk	End of October 2014	Malthe Winje Website	General public	>10000	World wide
18	Presentation on LinkedIn	Malthe Winje	MicroMilk	End of September 2014	LinkedIn	General public	>10000	World wide
19	Brochure	Van't Riet	Brochure for visitors of the Van't Riet and DanTech booth at Anuga Food Tech	March 2015	Cologne	General public, Potential customers	>100	World Wide
20	Oral Presentation	DanTech	Presentation at American Institute of Food Technology	27.07.2015	Chicago	General public	>1000	World Wide
21	Press release	DanTech	Press release to local news and Chamber of Commerce	11.10.2013	Burscoug h	General Public	>1000	UK

Strategy plan for exploitation of results and commercialization

Draft commercialisation plan: Our business idea responds to the market need of handling high-viscous products and particulates, primarily within the food industry. Our product, a 915 MHz continuous microwave system significantly increments the efficiency of existing systems by reducing overall operational costs related to downtime due to fouling by 50. C. Van't Riet will build, sell, install and provide services for the overall Microwave system and DanTec will supply the microwave components and construct the microwave transmitter. DanTech will also assist C. van't Riet with technical services related to microwave components and sells. Malthe Winje will provide the control system. In order to enable us to provide and sell the product the following actions are needed:

Improvement of system developed during MicroMilk-Demo Project to increase temperature stability of the system by hardware and software adaptations

Wide demonstration in different case studies and potential customer's products

Refinement of commercialization plan and intensification of marketing activities

The global market for our product represents 15 to 20% of the food processing equipment manufacturing (US $ 232.83 Billion worldwide in 2012), including pasteurizers, cookers and blanchers. The propose microwave system could cover all these applications for viscous foods especially for sauces, ice cream mixes, baby food, and pet food. Moreover, secondary markets may include other industries e.g. Biotech, pharma, environmental, etc, where a wide range of biomasses needs to be treated.

During the preparation of the business plan during this project we identified important market entry barriers and strategies to overcome them. Two Micromilk-Demo units have been presented at C. van't Riet and DanTec stands at the Anuga FoodTec 2015. According to the number of positive reactions at this exhibition we have the idea that there is a large market for this special treatment of liquid foodstuff since manufacturers from various food sectors approached to our stands. We do have a lot of addresses already and think that with some extra media attention we will reach our potential clients. We are definitely planning to participate on other food related exhibition coming year(s), e.g. FoodTec, Finland, Sept. 2016; FoodTech, Denmark, Nov. 2016; DrinkTec, Munich, Sept. 2017; Anuga FoodTech, Cologne March 2018.. Using our strong marketing experience and established international networks, we can ensure market entry. Building up strategic cooperations for technology transfer and services for this innovation is the key for our success in the market worldwide.

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