FCHR Report Summary

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Periodic Report Summary 1 - FCHR (Fluid Foods Pasteurizer and Homogenizer based on Centrifugal Hydrocavitation Reactor)

Project Context and Objectives:
The EU food and drink industry is the largest manufacturing sector in the EU, with €965 billion turnover (about 15% of total manufacturing turnover) in 2008, about 310.000 companies and 4.4 million direct employees. The SMEs, which account for 99% of the companies involved in the sector, represent 48% of the turnover and 63% of total employees.
As an example, the EU dairy industry, representing around 15% of the turnover of food and drinks industry in Europe, even remaining the world's number one cow milk producer with 142 mln tonnes, far ahead of US (80 mln tonnes) and India (38 mln tonnes), is facing increasing competition from emerging countries (China, India, US and South-America) and loosing export share: New Zealand is now the biggest exporter.
The most relevant challenges the sector is facing in the next future are:
1. Improve competitiveness of the processors, which is increasingly decisive for the pricing.
2. Uptake innovations linked to the health and well-being of consumers.
Process steps in which innovation could answer to both challenges are:
1. alternative treatments to pasteurization, which are becoming increasingly important due to a) consumer demand for new methods of food processing that have limited impact on the nutritional content and quality of food; b) need to improve the energy efficiency of the processes. Presently this process step is realized through conventional high temperature processes, which are both high energy consuming and can somehow alter the quality of the product. Hence effort is ongoing to explore new ways of introducing energy into the system.
2. Alternative more efficient processes for homogenizing, emulsifying, dispersing the fluid, which are commonly realised through rotating blades, mixers, or pumping devices with homogenizing valves that creates a narrow passage through which the product is forced to flow out. This process stage in the treatment of food provides improved product stability, shelf life, digestion, and taste.
Alternative "non-thermal" solutions for realising pasteurization and homogenization are being studied, such as pulsed electric field (PEF) and sonication through ultrasounds (US) or combination of these solutions.
These approaches are indeed more efficient in energy terms with respect to common thermal treatment, but have a main drawback linked to the difficult scalability.
For this reason the industrial application of these technologies is still difficult and commercial solutions are still only applicable at lab or very small production scale, while no industrial solution is presently available.

The FCHR project proposes the implementation of an integrated pasteuriser and homogenizer for fluid foods based on an alternative approach induced only by mechanical means: hydrodynamic cavitation, which consists in the generation of huge amounts of energy in the form of shock waves, due to the turbulence produced in a fluid by pressure fluctuations.

In fact, the turbulence creates pressure drops in local conditions, down to values lower than the partial pressure of the fluid, causing vaporization of the fluid in microbubbles of the order of hundreds nanometres up to a millimetre. In very short time these microbubbles implode due to the higher pressure surrounding them, and condensing reach high temperatures and release huge amount of energy in the form of shock waves (cavitation). This energy can be destructive in uncontrolled cavitation produced in turbo expanders, causing the destruction of impellers, but can be used for disinfection and heating in devices with specific design in which cavitation occurs in a controlled and non destructive way.
The project is promoted by the company Wixta Industries who has patented an innovative configuration of Centrifugal Hydrocavitation Reactor (CHR). The reactor has been devised for heating and vaporization of fluids and has been first tested in laboratory with the support of the University of Rome Tor Vergata (UTV), allowing to confirm that the reactor is able to continuously increase the temperature of a liquid flow of 300 l/h of 25°C with efficiency of 84%.
Although the design and the control of cavitation effect were not optimised in the prototypes implemented so far and a large margin of improvement is expected, results confirm that the CHR technology:
1. can be effectively applied for liquid heating (or vaporisation) through mechanical device.
2. can act as a highly efficient homogenizer/emulsifier

Starting from the promising results produced in these applications, the objective of the project is to specialise the CHR concept to the needs of the food sector, producing a reactor which can act both as pasteurizer and homogenizer in a single process step, with an outstanding advantage for the food manufacturers in terms of energy efficiency and quality of the product. Even though the CHR designed by Wixta has so far not been tested for this application, it is worth noticing that the use of controlled hydrodynamic cavitation for fluid food pasteurization or sterilization has been already studied in some scientific works.

Strategic value statement: Increase the competitiveness of fluid food producers thanks to process intensification and energy efficiency while keeping the integrity of food nutritional and flavor attributes.
The FCHR technology is applicable potentially to all fluid food in which pasteurisation and homogenization is needed: all products in the dairy industry, emulsions of flavorings, fruit nectars, vegetables puree, egg yolks, sauces and tomato sauces, formulations for early childhood, etc. The potential application to these products, and to intermediates used for their production, represents a huge potential market for the technology.

The application to the food sector, even though promising on the basis of the potential applications, is a completely new sector for the CHR. To promote this application, Wixta has partnered with the other SMEs involved in the proposal, to create a complete value chain for the exploitation of the results:
• An SME with specific expertise in motor controllers for the development and commercialisation of the FCHR (ELEC from Malta)
• An SMEs with relevant market position in the plant design and development in the food industry (FENCO from Italy)
• An end user, producer of apple juices, that will be able to evaluate the applicability of the FCHR to this food (EPLE from Norway).
• An end-user in the milk production and processing sector, which will be in charge of evaluating the applicability of the FCHR system on milk (GLENILEN from Ireland).

It must be stressed that the relevance of the proposed results has been recognised by the top level food manufacturer group BARILLA, which operates in Italy, the United States, France and Germany, with a global turnover of Euro 4 billion in 2010, recognised as the 1st most reputable company in the world in the global food sector, by a survey of the world's largest companies which considered product offering and services, innovation, workplace, governance, etc. (Global Reputation Pulse 2010). BARILLA has taken contacts with Wixta and is really interested to uptake the application of the FCHR in several processes and for production of innovative food products, in the hopeful case the outstanding targets of the technology will turn into results. Barilla will indicate one or two food matrixes which will undergo testing, and to evaluate the results produced by the R&D. The tangible outcomes of the FCHR project, available to SME partners for exploitation are:
1) Numerical simulation model of the hydrodynamic behavior inside the reactor and of the parametric design of the reactor: this model will be usable for optimisation of the cavitation inside the reactor and optimisation of design for other products in the food sector or for other kinds of applications.
2) CAD design of the FCHR reactor and definition of the plant layout for pasteurizer/homogenizer: the design is optimised for the application of following numerical simulation; the pasteurizing/homogenizing process is designed to be properly applicable at industrial scale.
3) Control system for the control of cavitation inside the FCHR: control strategy and algorithm; implementation of dedicated control electronics and software
4) Results of tests carried out on the prototype with different food matrixes.
Project Results:
The period between M1 and M9 of the project has been mainly devoted to carry out two types of activities. On the Management side, the whole Consortium was involved in:
1. The preparation of an agreed Consortium Agreement for the project revised by all the partners and submitted in its definitive, signed version.
2. The preparation of the First Periodic Report and of the related financial statements,
3. The submission of all the planned Deliverables for the period, and the supervision on their technical contents, on the base of what was originally planned as from the DoW,
4. The planning and organization of the general Project Meetings with all the partners, and the verification of the technical developments obtained by the RTDs in accordance to what is foreseen from the funding scheme, with an internal review procedure by the SMEs partners,
5. The management and coordination of internal technical meetings at WP level in order to monitor the status of the activities and to validate the results achieved.
On the technical side, the first 9 months of the FCHR project were mostly devoted to:
1. The internal discussions with the partners about what restrictions and constraints that should be considered for the FCHR pasteurizing system, and the establishment of the end-user and system requirements for both the lab-scale and the final prototype, including external requirements (Directives, national regulations, etc.) and desirable features that the beneficiaries considered could make more attractive for the future commercial use of the processing machine;
2. The identification of the technical specifications – components (sensors, valves, pumps, electronics, etc.) and of a general layout for both the lab-scale and the final prototype;
3. A study on the existing numerical models available for simulating the fluid-dynamic behavior and assess controlled cavitation in the reactor, as well as the realization of a fluid-dynamic model and of a parametric, 3D model of the reactor itself;

4. The design and implementation of a lab-scale prototype for microbiological and chemical/physical tests, able to assess pasteurization and homogenization in the treated food,
5. the development of a test protocol aimed at verifying the effect of the FCHR technology on raw milk and juices and the realization of preliminary tests at lab scale to evaluate the feasibility of the technology and the optimal conditions/parameters for achieving the desired conditions
6. The establishment of initial discussions among the partners aimed at identifying targeted dissemination and exploitation actions that the Consortium will put into practice for an optimal diffusion and promotion of the project, together with the collection of preliminary ideas for the preparation of a specific Plan for Use and Dissemination of Foreground document, at Month 9, indicating the approach that will be adopted after the end of project for the product commercialization of the pasteurizer/homogenizer.
7. The ideation and creation of a preliminary dissemination channel, i.e. the website, with a dedicated logo, and a first press release on the launch of the project.

As described in the DoW, the first period of the project was devoted to lay the basis for the design and manufacturing of the lab-scale FCHR reactor, following the organization of the work packages which mainly involved WP1, WP2 and WP3.
Dissemination activities and management of the Consortium (WP7 and WP8) were continuously ongoing activities in RP1, and produced outputs that will be detailed in the following sections of this report.
The structure of the workplan was kept identical to the original, despite some minor deviations that will be further analysed in this report; this structure was initially thought to have 3 main blocks of activities, constituting the heart of the whole implementation strategy for the FCHR system.
Summarizing:
- BLOCK 1: SIMULATION AND LAB RESEARCH– including the 3 activities aimed at:
o Collecting and organizing the users' needs and the system requirements,
o Gathering in a plenary discussion the functionalities that the system should have, and of identifying the specifications and layout of the lab-scale and of the final prototype, and
o Manufacturing the device for preliminary tests on the microbiological, chemical, physical and nutritional characteristics of the processed fluid foods.
This is a key activity of the whole project, as it defines the direction towards which the research activity will be oriented, paving the way for the concrete development of the reactor, and provides indications on the functioning and on the possible modifications to be done to the final prototype to improve the pasteurization and homogenization effects.

- BLOCK 2: PROCESS DESIGN AND ENGINEERING / INDUSTRIAL IMPLEMENTATION AND VALIDATION:
o Design and manufacturing of the reactor,
o Testing and scale up of the technology, and of
o Technology assessment in terms of performances and commercial potential.
The core of the project lays in the implementation and testing phase, and is expected to provide a major part of the results on the foods pasteurization / homogenization; to this end, great efforts have been planned to meet the project objectives of efficiency, sustainability and performance, and to validate the FCHR technology.

- BLOCK 3: INDUSTRIAL PERSPECTIVES – which includes:
o The diffusion of the project results through specifically planned dissemination activities, and
o The definition of an agreed vision on the exploitation phase of the project, once it has obtained its key objectives; this plan will be realized by the SMEs depending on their specific commercial interests and businesses.
This activity will mostly involve the SMEs, in the phase of promotion of the project and in the identification of the steps leading to a proper exploitation plan for the commercialization of the FCHR technology, this including joint ownership and commercial agreements among the SMEs.

We can summarize here the main goals achieved in the period WP by WP:
WP1: Definition of expected requirements for the FCHR pasteurizer/homogenizer from the end-user side (in terms of target product, selection of food matrixes for the tests, regulatory constraints, technical features, users' needs, etc.).
WP2: Development of numerical methodologies for simulating the fluid-dynamics inside the reactor, evaluation of the effects of the variation of the parameters affecting cavitation and their dependency.
WP3: Manufacturing of the lab-scale prototype and implementation of preliminary tests at lab scale to evaluate the dependency of the working parameters on the microbiological and physical results desirable for the FCHR..
WP7: Definition of an exploitation route for the results, definition of commercial agreements among the partners and diffusion of the project to the external public.
WP8: Coordination of the Consortium, planning and revision of the activities and quality control, monitoring of the work progress and management of the possible deviations from the original plans.

Finally, let us consider the milestones table: the most of the core objectives for the FCHR project have been planned for the second period. However, basic results have been fixed for RP1 as a means of verification of the overall process validity and

feasibility against the established requirements and specifications. As will be detailed in the dedicated section of this report, both MS1 and MS2 have been achieved. In fact:
a) The fluid-dynamic model of the reactor was properly carried out by UTV and the results on assessing controlled cavitation inside the reactor were detailed in D2.2 (and D2.3);
b) The lab-scale solution for the FCHR pasteurizer/homogenizer was delivered to Cork and preliminary microbiological and physical tests allowed to identify the working parameters to be improved for the hopeful achievement of the desired specifications. Delays in the implementation of the lab scale prototype (discussed in the later section) did not allow the completion of the testing phase and the complete assessment of the feasibility of the solutions. Optimisation tests foreseen in the RP2 in task 3.3 will proceed and complete the assessment of this milestone. As a general consideration, and following the summary of the achieved results for Period 1, we can state that:
As a general consideration, and following the summary of the achieved results for Period 1, we can state that:
Most of the strategic and operative goals of the first period have been achieved, with some deviations with respect to the original workplan, that have been faced timely and with success. The details of how these issues were managed will be presented partly in the WPs description, and discussed later in this report (Management section).
Potential Impact:
Starting from state-of-the-art knowledge and technologies, the main objective of the project is to specialise the centrifugal hydrodynamic reactor concept to the needs of the food sector, producing a reactor which can act both as pasteurizer and homogenizer in a single process step, with an outstanding advantage for the food manufacturers in terms of energy efficiency and quality of the product.
To reach this objective, the FCHR Consortium established a set of strategic objectives, of operative goals and of quantitative targets to be achieved with the new pasteurizing/homogenizing method. In particular:

STRATEGIC OBJECTIVES
S.O.1. To perform pasteurization and homogenization in a single process performed with a purely mechanical technique, which is therefore highly scalable, due to the absence of electric field or ultrasound emitters.
S.O.2. To substitute thermal pasteurization with a process working at lower temperature, while delivering a safe product that preserves the sensory characteristics and freshness
S.O.3. To reduce processing cost, thanks to improvement in energy efficiency in the manufacturing steps (pasteurization and homogenization).

OPERATIVE OBJECTIVES
O.O.1. To optimize the design of the reactor and the rotor for the specific food industry needs, in particular for an industrial homogenizer/ pasteurizer, and aiming to reach a controllable cavitation.
O.O.2. To produce the mechanical design of the reactor on the basis of results of CFD simulations and define the structural control, noise reduction and material selection through structural simulations, to avoid any wear.
O.O.3. To implement a specific control system for the control of cavitation and of the pasteurising/homogenizing process.
O.O.4. To test the microbiological, chemical, physical and nutritional quality of 2-3 food products selected, inoculated with different kind of microorganisms, both on a preliminary non optimised small scale reactor and a large size optimised prototype of FCHR, under different operative conditions.
O.O.5. To define a pasteurizing/homogenizing process design properly applicable at industrial scale in order to meet the specifications and regulation of the food production.
O.O.6. To evaluate the installation and operating costs of the pasteurizing and assess the technology against commercial benchmark from the different points of view: energetic, economic and quality of the products.

QUANTITATIVE TARGETS
Q.T.1. Size of reactor: 60 cm diameter of the stator for the single module
Q.T.2. Production capacity: 2000-3000 l/h with a module. Capable of being easily scaleable with parallel reactors with flowrates of several thousand litres per hour.
Q.T.3. Target exit temperature of the fluid: < 60°C (to be evaluated according to results of microbiological tests) with temperature increase of 30°C in the reactor.
Q.T.4. Targeted sterility: Equivalent to pasteurisation at a minimum – i.e., inactivation of Mycobacterium tuberculosis and alkaline phosphatase enzyme.
Q.T.5. Energy efficiency: Thermal efficiency of heating > 90%, same as heat exchanger; Energy saving for overall pasteurization and homogenization > 15%;

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Target market for FCHR is pasteurizing and homogenizers equipments in the replacement and new plants in fluid food manufacturing: dairy industry, canning industry, condiments and sauces. The dairy sector recorded a particularly weak performance with regards to exports, losing on average 20% in export value in 2009 compared to 2008. However, it continues to be the fourth most important export product of the EU food and drink sector and the most innovative among the food sectors in Europe. For these reasons, this sector can be considered the primary reference market for the FCHR technology. However, also the canning industry is a relevant market where the results could be applied.
The objective of FCHR Consortium is to reach after 5 years of market development of the technology a market share of 5%. The market penetration would be based on an initial lower number of plants, going in parallel with the marketing phase, reaching the target number at year 5. It should be considered that the number of plants expected to be sold by FENCO, exclusive manufacturer on territorial/sector basis, is estimated to be 33% of the total number indicated. The remaining plants would be manufactured by other licensees of the technology in other sectors/markets.
The mechanical treatment introduced in FCHR will bring the following impact in the the dairy market operation and business:

1) Scalability: the system will be easily scalable with parallel reactors with flowrates of several thousand litres per hour.

2) Energy Savings: it has been estimated that the FCHR process, coupling the two actually separate processes of pasteurization and homogenization of fluid foods, and mostly of milk, will allow for an energy saving of about 20% with respect to the actual expenditure for a mill processor; this is an important advantage of the FCHR technology, if we consider that pasteurization is the most energy-demanding process, representing (for milk, as an example) about 33% of heat and the 20% of the global electrical consumption for the overall process, so that energy saving becomes a crucial target for the project;

3) Pasteurization grade: Equivalent to that of traditional pasteurization;

4) Digestibility and quality of food: the new process will grant higher digestibility especially in the case of milk; in fact, lower temperatures are needed to achieve the same pasteurization grade, thanks to the cavitation energy, with respect to thermal gradient. This reduces the degradation of the nutrients and keeps the flavor of the food (white color enhanced for milk, quality problems such as “sweet curdling” due to enzymatic action and oxidation are minimised).
5) Energy Efficiency: thermal efficiency of heating > 90%, same as a heat exchanger;

All these features of the FCHR reactor will allow the dairy SMEs in Europe to increase their competitiveness and a valuable economic advantage will be gained with respect to traditional methods for pasteurization and homogenization. The potential market for the FCHR is therefore outstanding, due to the huge range of possible applications in the food sector and to the relevant number of involved SMEs in EU. Only considering the application to the dairy and canning sectors, with a market penetration reaching 5% of the plants installed after 5 years from the commercialisation of the FCHR plants (about 115 plants/year of medium size), it has been estimated that the profits for the SMEs participants will get to about 6 M€/y.
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