DairyWater: Sustainability and resource efficiency for the Irish dairy processing industry

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Abstract

The abolishment of milk quotas in 2015 is expected to result in a 50% increase in milk production in Ireland by 2020. This increase in the volume of milk being processed, along with stringent measures on emissions from the industry and growing commercial drive for operational efficiencies, is driving the need for innovative technological and operational solutions within the dairy processing industry. In this context DairyWater, a new multi-stakeholder research project, is developing innovative solutions for the efficient management of water consumption, wastewater treatment and the resulting energy use within the country's dairy processing industry. This project has the potential to position Ireland at the forefront of European, or indeed international, research in this sector as it strives to make the Irish dairy processing industry more efficient and environmentally sustainable by reducing carbon footprints, energy and water use. This will, in turn, lead to greater potential for exports, increased international competitiveness for Irish products and stimulate job creation. The primary goal of the study is to efficiently and effectively treat wastewater effluent from dairy processing plants using a range of innovative biological, nanometerial-based and disinfection technologies. In parallel, the efficient use of water (and resulting energy costs) within the plants is also being explored.

Keywords: dairy; environmental impact; Ireland; milk processing; water consumption; water reuse; wastewater treatment technology.

1. Introduction

Ireland is one of Europe's largest producers of cow's milk with an annual production of over 5 million litres (CSO, 2014). Currently, dairy ingredients and products comprise almost 30% of the Irish food and drink export market and, in 2013, dairy ingredients and products surpassed €3 billion for the first time (National Milk Agency, 2014). This export market is expected to increase due to the abolition of milk quotas and increasing international food demands. A summary of the trends in dairy manufacture between 1992 and 2014 is presented in Figure 1. Furthermore, the milk quota system, that has been in place in European, which restricted milk production, was abolished on 31st March 2015. The result is an expected increase in milk production in Ireland of 50% by 2020 (DAFF, 2010). This increase in the volume of milk being processed, along with stringent measures on emissions from the industry and growing commercial drive for operational efficiencies is driving the need for innovative technological and operational solutions within the dairy processing industry.

In this context DairyWater, a multi-stakeholder research project, is developing innovative solutions for the efficient management of water consumption, wastewater treatment and the resulting energy use within the country's dairy processing industry. DairyWater is led by Prof. Xinmin Zhan in Civil Engineering, College of Engineering and Informatics and the Ryan Institute at the National University

of Ireland Galway. The project runs for 4 years until the end of 2017 and involves 5 leading Irish research institutes:

- National University of Ireland Galway
- University College Cork
- Trinity College Dublin
- Athlone Institute of Technology
- Teagasc.

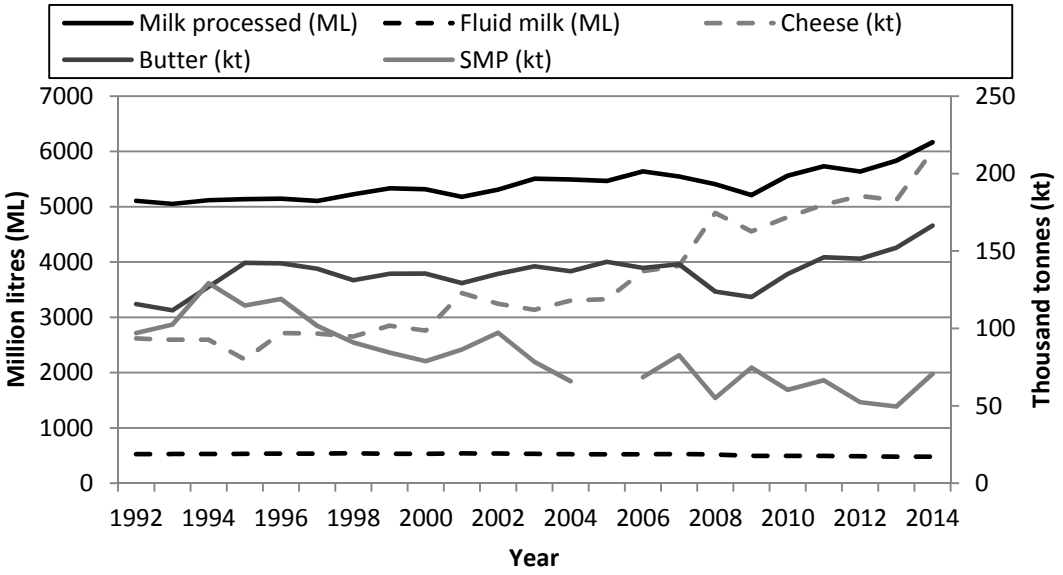


Figure 1: Trends in dairy statistics between 1992 and 2014 for volume of milk processed and selected dairy products (fluid milk, butter, cheese and skimmed milk powder (SMP)), data obtained from CSO (2014)

In this paper, the main research areas, and the associated task objectives, are discussed. The close links that the DairyWater project has with the Irish dairy processing industry are explained and the positive impacts that the project may have on the industry are described. Additionally, the surveys completed at dairy processing plants and other progress to date is outlined.

2. Project research topics

The research proposed in the DairyWater project is centred on dairy wastewater treatment technologies but also encompasses aspects of water reuse and the environmental impacts of the Irish dairy processing industry. A schematic depicting the various tasks and research groups within the DairyWater project is presented in Figure 2. Therefore, the project can be divided into three main research areas:

- Dairy wastewater treatment technologies;
- Water re-use and rainwater harvesting; and
- Environmental life cycle assessment (LCA).

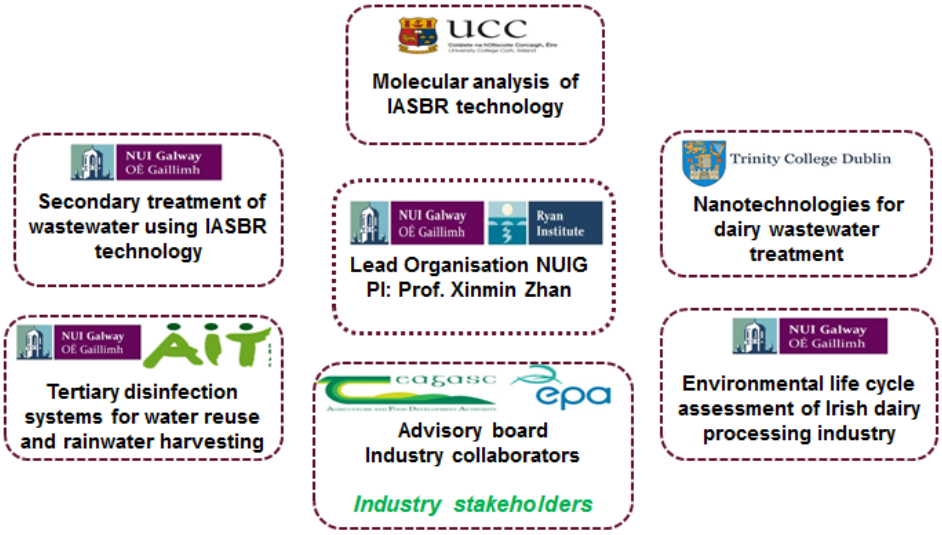


Figure 2: Schematic depicting the various tasks and research groups within the DairyWater project

2.1 Dairy wastewater treatment technologies

One of the most central aspects of the project is the development of novel technologies for the treatment of dairy wastewaters. When dealing with wastewater from dairy processing plants, the most problematic nutrients are nitrogen and phosphorous. The intermittently aerated sequencing batch reactor (IASBR) technology, developed at NUI Galway, will be investigated as previous studies dealing with pig production facilities have shown it has the potential provide an economical solution for nutrient removal (Pan et al., 2013). This novel technology operates in a sustainable and cost efficient manner and could become a key tool as the increase in production is expected to lead to a corresponding increase of wastewater production.

Initially, laboratory-scale experiments will be performed in order to determine the effectiveness of the technology in the dairy processing sector. An image of the laboratory-scale IASBR experimental unit at NUI Galway is shown in Figure 3. Following this, a pilot-scale onsite system will be constructed at a selected dairy processing plant. This will give a greater insight into the performance of the IASBR technology at a more commercial scale.

Figure 3: Laboratory-scale intermittently aerated sequencing batch reactor experimental unit at NUI Galway

Therefore, the main aim of this project task is to investigate whether the IASBR technology can be used to treat dairy processing wastewater effectively and more efficiently in terms of energy and cost. Additionally, working alongside project partners UCC, the microbiological communities will be examined at various points in the IASBR cycle to fully understand the nutrient removal mechanisms which occur in the IASBR.

The shift of the microbial ecological structure in laboratory-scale and pilot-scale IASBRs will be determined through molecular microbial ecology studies performed at the Environmental Research Institute, UCC, using advanced pyrosequencing techniques. This will aid in the development of bioreactor sampling regimes to obtain representative samples from established reactors and establishment of relevant sample storage and processing protocols. Additionally, this will give a greater understanding of the unique nutrient removal mechanisms of the IASBR technology, which will aid in significant increases of efficiencies in reactor design and operation, improve nutrient removal rates while decreasing costs and energy usage.

The use of nano-materials to improve the efficiency of wastewater treatment processes in this sector has not previously been well explored. DairyWater, at the Centre for Research on Adaptive Nanostructures and Nano-devices (CRANN) in Trinity College Dublin, will develop novel and low cost nano-materials that can greatly enhance treatment performance while reducing energy and operational costs. With the application of nano-materials within many engineering sectors, this could be one of the major leaps in the development of new and innovative engineered systems in the water and wastewater sectors. The effectiveness of the nano-material technology will be evaluated in both laboratory-scale reactors and full-scale systems.

2.2 Water re-use and rainwater harvesting

Along with the effective treatment of dairy wastewaters, a study into the efficient use of water within dairy processing plants is also being addressed within the project. Water consumption ratios in the Irish dairy sector are approximately $2.5m^3/m^3$ milk processed (Geraghty, 2011). However, water is also used for other activities within the plant such as steam generation, cooling duties and cleaning in place (CIP). Of these, studies have shown CIP duties to account for the majority of water consumption in dairy plants with the average annual volume of water use per plant in Ireland estimated at 875,000 m^3 (Geraghty, 2011).

Indeed, water consumption rates have decreased in recent years in terms of quantities used for product make-up however fieldwork surveys on Irish dairy plants have revealed that the majority of water utilised outside of food production is not reused within the plant nor is the treated wastewater effluent. Tertiary treatment technologies applicable for dairy wastewater reuse include membrane filtration, ultraviolet irradiation (UV) and ozone treatment (Fitzhenry et al., 2014). An example of the tertiary process water treatment system on-site at the Kerry Group dairy plant, Listowel, Co. Kerry, is depicted in Figure 4. While membrane filtration can restore used water to potable standards, it can be expensive and labour intensive. UV and ozone treatment may be used to produce water to CIP standards which could decrease costs while providing enhanced pathogen free wastewater. In addition, rainwater harvesting also has the potential to decrease water consumption by utilizing on-site storm water and tertiary treatment technologies. The innovative technologies explored will be trialled at both laboratory-scale and at a demonstration site to accurately quantify their effectiveness. Therefore, the aims of this task are:

1. to investigate the use of the innovative pulsed UV systems, developed by Athlone IT and NUI Galway, and ozone as tertiary disinfection systems for dairy wastewater effluent
2. to evaluate the potential for water and wastewater reuse within dairy plants
3. to analyse the potential for on-site rainwater harvesting at dairy plants

Figure 4: Tertiary process water treatment system on-site at the Kerry Group dairy plant, Listowel, Co. Kerry

2.3 Environmental life cycle assessment

Using the data obtained from the various dairy processing plants, an environmental life cycle assessment of the main dairy products manufactured within the Republic of Ireland will be performed. Along with performing an assessment of Irish dairy products, an assessment of individual plants and the potential positive impact of novel technologies investigated in this project will be carried out. In order to achieve this, three types of life cycle assessments will be performed:

1. A macro-scale life cycle assessment of the main dairy products produced in the Republic of Ireland from cradle to the processing factory gate (Finnegan et al., 2015)
2. An environmental life cycle assessment of selected dairy products in the Republic of Ireland from farm gate to the processing factory gate
3. An environmental life cycle assessment comparing existing dairy wastewater treatment technologies to the technologies developed in the DairyWater project

The results of this study will serve as a benchmark for the Irish dairy industry as individual producers and processers can evaluate and compare their performance in comparison. The results of the study may also be used as an international comparison for dairy processing industry studies.

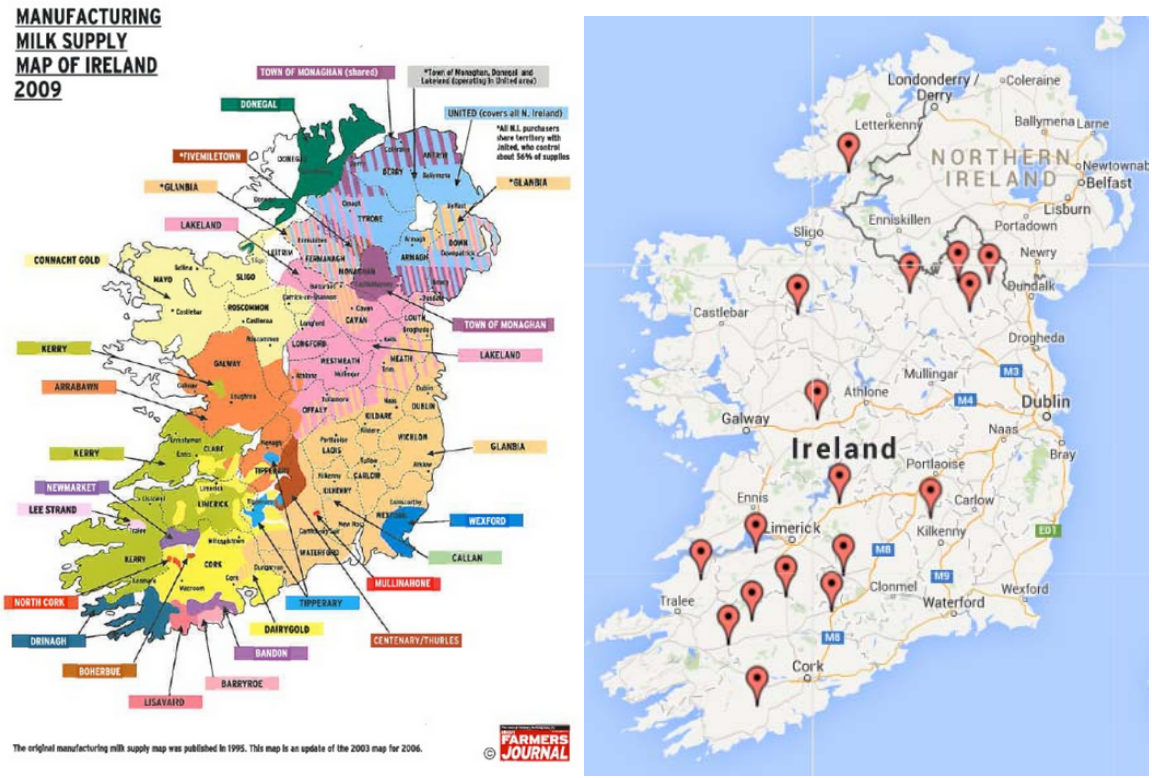
3 Industry Liaison

In order to ensure that the research within the project remains relevant to the Irish dairy processing industry, the project team are working closely with leading industry stakeholders. Since the projects' inception, a number of dairy companies have agreed to help by providing information and facilitating site visits. These companies are:

- Abbott Ireland
- Arrabawn Dairies
- Aurivo

- Carbery
- Dairygold
- Glanbia
- Kerry Group
- Lakeland Dairies

Representatives from these dairy companies will sit on a project advisory board, which also includes representatives from a number of government funded bodies (Enterprise Ireland, the EPA and Teagasc). The project advisory board will meet annually to discuss the progress and the direction of the project. The industry partners will, also, facilitate pilot scale activities during the project; thus enabling potential commercial benefits of this research to be realised. Figure 5 (a) depicts the milk suppliers to the various dairy processing companies in Ireland while Figure 5 (b) shows a summary of the dairy processing plants which are currently involved, or will be involved by project completion, within the DairyWater project.



(a) **(b)**

Figure 5: Map of the dairy industry in Ireland: (a) milk suppliers to the dairy companies (b) dairy plant locations which are involved in the DairyWater project

4 Conclusion

The main objectives of the DairyWater project, along with a detailed description of the main research areas, have been discussed in this paper. DairyWater has the potential to position Ireland at the forefront of European, or indeed international, research in this sector. The project strives to make the Irish dairy processing industry more efficient and environmentally sustainable, which will lead to greater potential for exports and increased international competitiveness for Irish products, along with stimulating job creation.

To date, detailed surveys of a number of plants, including site visits, have been completed, which has given researchers an insight into the plants' energy usage, water consumption, resource usage and wastewater treatment facilities. Furthermore, information relating to the main challenges affecting the industry, currently and in the future, has been provided. The next phase of the project involves the laboratory-scale testing of the proposed technologies and the continuation of site visits and plant interactions, in order to increase the knowledge base of the research personnel.

With the abolition of the quota system in March 2015, the Irish dairy industry is going through an exciting but challenging time. The novel technologies explored and studies performed during the DairyWater project may prove invaluable if the Irish dairy industry is to remain competitive in an ever-changing international market.

Acknowledgments

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