Water consumption and direct energy use in the Irish dairy processing industry

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Abstract

In 2015, the milk quota system that is in place in Europe is to be abolished, instigating an increase in milk production. This increase will aid in addressing the world's ever growing demand for food but will incur increased stresses on the environmental impact and sustainability of the dairy industry. In this paper, aspects of the environmental sustainability of the Irish dairy processing industry are assessed by calculating two key performance indicators for 2013: water consumption and direct energy use. Water consumption was found to be approximately 2.28 m^3/m^3 milk processed. The energy usage is estimated to be 474 kWh/m^3 milk processed, which is made up of 114 kWh/m^3 milk processed in electrical energy and 360 kWh/m^3 milk processed in thermal energy.

Keywords: dairy; key performance indicators; Ireland; milk processing; water consumption.

1. Introduction

The dairy ingredients and products industry is Ireland's largest indigenous industry and comprises a vital part of the agri-food sector. Ireland is one of Europe's largest producers of cows' milk with an annual production of over 5 billion litres (CSO, 2014). Additionally, dairy ingredients and products contributes to 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). However, the Irish industry is about to embark on a period of significant change with the abolition of milk quotas in 2015, where a 50% increase in milk production by 2020 is expected (DAFF, 2010). As a result of this increase, resource usage will become an even greater concern than ever before. Therefore, efficient and effective management of resources will greatly influence the growth and competitiveness of this industry. The sustainability of the dairy industry in Ireland will be a major factor over the coming years as the industry transitions to 'life after quotas'. Sustainability of an industry is quantified using three main aspects: economic, social and environmental impacts.

The study presented in this paper forms part of the environmental assessment aspect of the DairyWater project, which aims to aid in increasing sustainability and resource efficiency in the Irish dairy processing industry. Within the project, the environmental impact of product manufacture within the Irish dairy processing industry is assessed using life cycle assessment (LCA) and key performance indicators (KPIs). Two of the KPIs addressed in the project are water and energy consumption, which also up part of the life cycle inventory within the LCA.

In recent years, a number of studies relating the water consumption in dairy product manufacture have been performed, including the publication of a special issue of the International Dairy Journal (Miller and Wang, 2013), which included the water footprint of US milk. Furthermore, Ridoutt et al. (2010) discussed the water footprint associated with dairy products using a case study involving skim

milk powder production in Australia. Additionally, Murphy et al. (2014) explored the direct water use on 25 Irish dairy farms and found that approximately 6.4 L of water was used for every 1 L of milk produced. With the introduction of the ISO 14046: water footprint guidelines (ISO, 2014), the International Dairy Federation (2014) has begun working on a water footprint guideline specific to the dairy industry.

In this paper, the water consumption and direct energy use associated with the Irish dairy processing industry are assessed. In order to provide an accurate assessment of the industry, data was used from 18 dairy processing plants located in the Republic of Ireland, which accounts for over 95% of the total raw milk processed in the Republic of Ireland in 2013. Furthermore, a breakdown of water sources and energy sources used by the industry is presented. Additionally, a discussion on the energy water food security nexus with respect to the Irish dairy processing industry relating to the water footprint associated with the energy carriers used.

2. Materials and methods

2.1 Irish dairy processing industry

The dairy processing plants manufacture the various dairy products where the primary ingredient is raw milk. At the plant, milk is tested for acceptability before being pumped into storage silos. It is separated into skim milk and cream, then pasteurised, followed by additional processes depending on the desired product. The product is packaged and stored before being distributed.

In 2013, the Irish dairy processing industry processed 5830.7 million litres of raw milk, which comprised of 5420.2 million litres of raw milk from domestic production and 410.5 million litres of imported raw milk (CSO, 2014). Each year, all dairy processing plants that receive greater than 200 tonnes of milk per day (averaged on a yearly basis) are required to report annually to the Irish Environmental Protection Agency (EPA). Within this report, details of emissions to air, emissions to water, energy consumption and water consumption are reported. Therefore, the quantities of electricity, fuel and water consumption are obtained from the annual environmental reports (AER) of each of the dairy processing plants analysed in this study (EPA, 2012). Additional information, including quantities of raw milk processed, energy usage and water consumption, were obtained from plant surveys, discussions with plant employees and company websites. Data obtained from 12 companies (18 manufacturing plants), which represents over 95% of the total raw milk processed in the Republic of Ireland (5830.7 million litres in 2013 (CSO, 2014)), was used in this study. The dairy processing plants detailed in this study process on average 315 million L raw milk year^{-1}, which varied between 80 million L raw milk year^{-1} and 1,350 million L raw milk year^{-1}.

The electricity mix in the Republic of Ireland in 2013 was reported as: natural gas 47.9%; coal 22.2%; peat 11.6%; renewables 12.8%; and other 5.5% (SEAI, 2014).

2.2 Environmental sustainability key performance indicators (KPIs)

In order to assess the environmental sustainability of the dairy processing industry, a range of KPIs may be used. The KPIs used to assess the environmental sustainability performance of the Australian dairy manufacturing industry during 2010/2011 (Barr and van Burren, 2013) were:

- Water consumption

- Energy usage
- Greenhouse gas emissions
- Packaging used
- Solid waste/bi-products produced
- Wastewater produced
- Chemicals usage

In this study, two of these environmental sustainability KPIs are discussed: water consumption and energy usage. The functional unit, which the results are normalised against, used in this study is a cubic metre of milk processed (m^3 milk processed). The results of the study are compared to the Australian industry (Barr and van Burren, 2013) and discussed. Additionally, details relating to the greenhouse gas emissions of the Irish dairy processing industry in 2012 are discussed in Finnegan et al. (2015).

3. Results and discussion

3.1 Water consumption

When dealing with a perishable product, such as milk, a reliable and clean water source which provides constant cleaning is essential. In 2013, from the plants surveyed, the total water consumption was reported as approximately 13 billion litres, which is sourced from: surface water (58%); groundwater (40%); public supply (2%), as shown in Figure 1. The availability of an open water source in order to minimise the use of public supply is the main factor in selecting a water supply source, as pumping and tertiary treatment costs are significantly lower than the tariff associated with using public supply. Therefore, many plants are located near a large water course, which is also beneficial for disposing of effluent from their on-site wastewater treatment facilities.

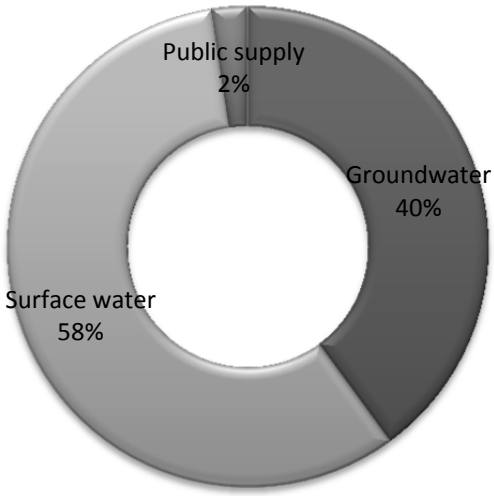

Figure 1: Breakdown of water sources used in the Irish dairy processing industry in 2013

Water consumption, in 2013, was found to be approximately 2.28 m^3/m^3 milk processed, which is a reduction of 9% on the 2009 figure of 2.5 m^3/m^3 milk processed (Geraghty, 2011), which can be seen

in Figure 2. Additionally, this shows a reduction of 26% between 2005 and 2013. However, in Australia, the figure in 2010/2011 was 1.75 L per L of raw milk processed (Barr and van Burren, 2013) and, therefore, there is potential for improvements of water use strategies in Ireland.

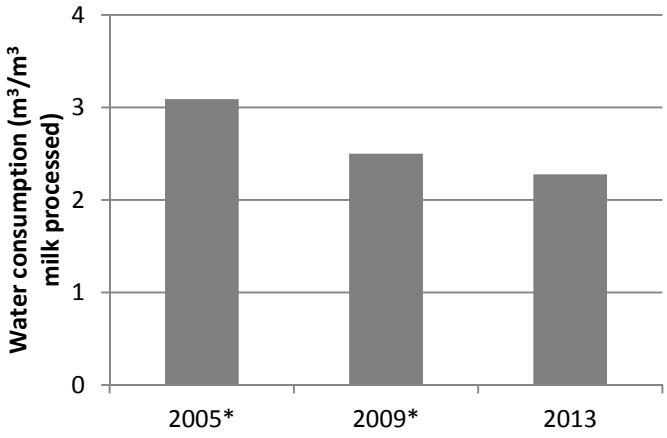

Figure 2: Direct water consumption within the Irish dairy processing industry in 2005, 2009 and 2013, where * indicates data obtained from Geraghty (2011) (units: m^3/m^3 milk processed)

Since approximately 87% of milk is water, an abundance of water is generated, in the form of condensate, in the production of powder products. Additionally, in 2005, the Australian dairy manufacturing industry sources 17% of its water from recycled concentrate (Prasad, 2006). These, along with a number of others, such as more efficient boilers, cooling towers and clean-in-place systems, will need to be implemented if water consumption within the Irish dairy processing industry is to be reduced.

3.2 Energy usage

The main energy users within dairy processing plants are steam production, processing, cooling, air compressors, clean-in-place systems and utilities. In 2013, from the plants surveyed, the total energy usage was reported as approximately 2.7 TWh, which is made up of 0.6 TWh in electrical energy and 2.1 TWh in thermal energy. Natural gas provides approximately 67% of the energy used in the Irish dairy processing industry with the remainder sourced from grid electricity (13%), fuel oil (13%) and coal (6%), which can be seen in Figure 3. Direct energy use is split up into electrical energy, which is comprised of electricity from the Irish grid (55%) and on-site generated electricity from combined heat and power (CHP) systems (45%), and thermal energy, which is derived mainly from natural gas, coal and fuel oil. CHP offers an inexpensive alternative to grid electricity, while also reducing the GWP associated with on-site energy usage. However, the majority of energy used is thermal energy.

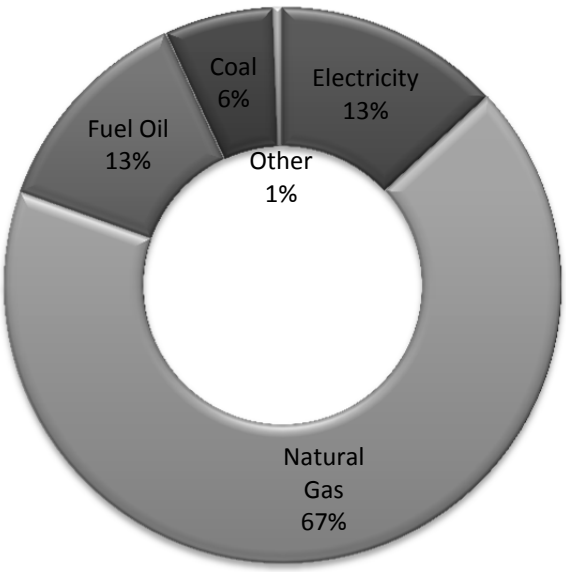

Figure 3: Breakdown of energy carriers used in the Irish dairy processing industry in 2013

The energy usage, in 2013, is estimated to be 474 kWh/m^3 milk processed, which is made up of 114 kWh/m^3 milk processed in electrical energy and 360 kWh/m^3 milk processed in thermal energy. It is evident from Figure 4 that there is an increase in electrical energy and a decrease in thermal energy since 2009. These differences may be attributed to the method of allocation of energy when dealing with CHP systems between the study conducted by Geraghty (2011) and the current study. There is a slight increase (2.6%) in energy usage compared to the 2009 figure of 462 kWh/m^3 milk processed (Geraghty, 2011) but a significant decrease (13%) compared to the 2005 figure of 527 kWh/m^3 milk processed (Geraghty, 2011). A possible reason for this increase could be increased monitoring of energy usage in recent years in an attempt to reduce energy usage. However, in Australia, the figure for energy usage in 2010/2011 was estimated to be 392 kWh/m^3 milk processed (Barr and van Burren, 2013) and, therefore, there is potential for improvements of water use strategies in Ireland.

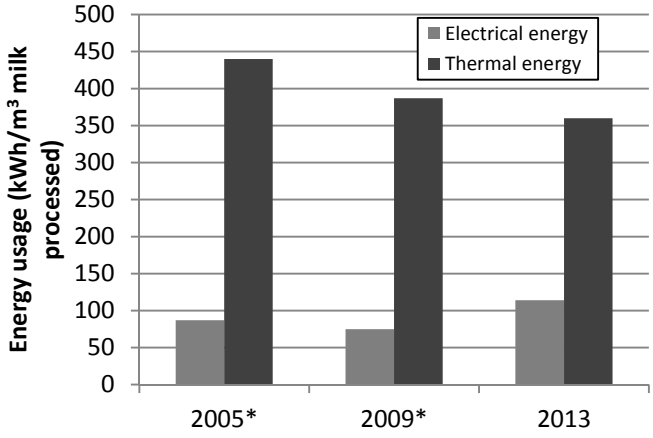

Figure 4: Direct energy usage within the Irish dairy processing industry in 2005, 2009 and 2013, where * indicates data obtained from Geraghty (2011) (units: kWh/m^3 milk processed)

3.3 Energy water security nexus

As the use of water and energy is the main topic of discussion in this paper, it is fitting to discuss the energy water food security nexus with respect to the Irish dairy processing industry. The aspect discussed is related to the water footprint associated with the extraction and production of energy carriers. In order to estimate this for the Irish dairy processing industry, the average water footprint figures specified by Gerbens-Leenes et al. (2008), which are presented in Table 1, are used. The results presented in this section are an estimate and a more detailed study, which would give a more definitive solution, should be compiled using the ISO framework (ISO, 2014).

Using the factors presented in Table 1, the water footprint associated with the production of grid electricity in Ireland is estimated to be 0.11 m^3/GJ. However, within this calculation, it was assumed that renewables referred only to electricity from wind energy and peat was treated as coal but, as the assumptions only affect a small proportion of the overall figure, the assumptions were deemed reasonable. Therefore, using the breakdown presented in Figure 3, the water footprint associated with energy usage is estimated to be 0.4 m^3/m^3 milk processed, which is approximately 18% of the average direct water consumption.

Table 1: A summary of the average water footprint associated with selected primary energy carriers (Gerbens-Leenes et al., 2008)

Energy carrier	Average water footprint (m^3/GJ)
Coal	0.16
Crude oil	1.06
Natural Gas	0.11
Electricity from wind energy	0.00
Electricity from solar active space heat	0.27
Electricity from hydropower	22.3

4. Conclusion

The water consumption and direct energy usage associated with the dairy processing industry in the Republic of Ireland is discussed in this paper. The results of the study are compared with a previous Irish study performed, in 2005 and 2009, and an increase in efficiency was observed. The results were also compared to an Australian sustainability study and it was evident that there is potential for improvements within the Irish dairy processing industry. The DairyWater project, which this study is a part of, includes a research task which explores the possibility of water reuse within dairy processing plants. The results of this task may aid in improving the water consumption within the industry.

The next phase of this research is to complete the remainder of the KPIs in order to compile a completed report on the environmental sustainability of the Irish dairy processing industry. Using a similar Australian study as a benchmark, the areas where sustainability can be increased will be evident. Furthermore, an environmental life cycle assessment of selected dairy products within the Irish dairy industry, for a number of environmental impact categories, will be performed.

Acknowledgments

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