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Environmental impacts of milk powder and butter manufactured in the Republic of Ireland

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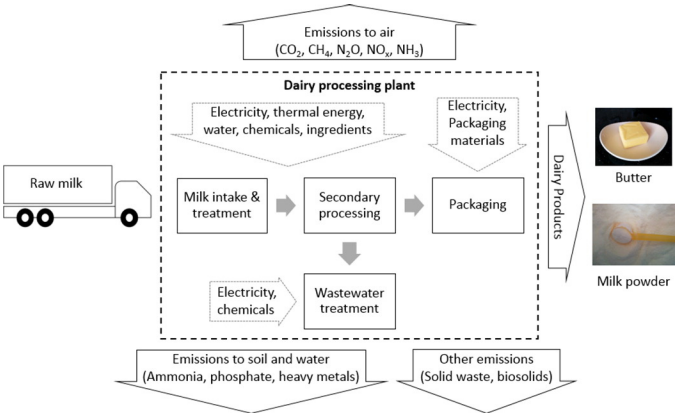
HIGHLIGHTS

- Environmental impact of milk powder and butter manufactured in Ireland is assessed.
- The post-farm GWP of 1 kg milk powder and 1 kg butter is 1.482 kg CO_2eq and 0.528 kg CO_2 eq, respectively.
- Evaporation and drying have most significant environmental impact in milk power manufacture.
- Refrigeration uses 39% of the total electrical energy in butter manufacture.

GRAPHICAL ABSTRACT



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ABSTRACT

The abolition of the milk quota system that was in place in Europe was abolished in 2015, which instigated an immediate increase in milk production in many European countries. 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 study, an environmental life cycle assessment was performed in order to estimate the environmental impacts associated with the manufacture of milk powder and butter in the Republic of Ireland. A farm gate to processing factory gate analysis, which includes raw milk transportation, processing into each product and packaging, is assessed in this study. Operational data was obtained from 5 dairy processing factories that produce milk powder (4 of which also produce butter).

Results for each environmental impact category are presented per kilogram of product. Energy consumption (raw milk transportation and on-site electrical and thermal energy usage) contributes, on average, 89% and 78% of the total global warming potential, for milk powder and butter respectively, for the life cycle stages assessed. Similarly, energy consumption contributes, on average, 86% and 96% of the total terrestrial acidification potential for milk powder and butter respectively, for these life cycle stages. Emissions associated with wastewater treatment contribute approximately 10% and 40% to the total freshwater eutrophication potential and marine eutrophication potential, respectively, for both milk powder and butter production. In addition, packaging materials also has a significant contribution to these environmental impact categories for butter production.

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Results were also presented for three milk powder products being manufactured by the factories surveyed: skim milk powder, whole milk powder and full fat milk powder. The analysis presented in this paper helps to identify opportunities to reduce the environmental impacts associated with post-farm processing of milk powder and butter.

1. Introduction

Global milk production is estimated at approximately 735 billion L, where the largest producer is the European Union (EU) at 156 billion L (Fonterra, 2014). Furthermore, according to a European Commission report (EC, 2015), the annual growth rate of the global dairy industry is predicted to be 2.4% per annum, which is approximately 1.4 million tonnes of dairy products, over the next 10 years. If the EU is to meet its climate and energy targets for 2020 of a 20% increase in energy efficiency and a 20% reduction in greenhouse gas (GHG) emissions (EU, 2008), the dairy industry must strive to reduce impacts and increase sustainability to deal with this expected increase in milk production.

Currently, the Republic of Ireland is on the brink of a new era for the dairy industry. In March 2015, the European milk quotas, which restricted milk production since 1984, were abolished. As a result, milk production is expected to increase by 50% by 2020, based on the reference years 2007 to 2009 (Farrelly et al., 2014), with a yearly increase of approximately 35% observed since March 2015 compared to the reference years (Fig. 1). This brought the total milk produced on dairy farms in the Republic of Ireland in 2015 to a record high of 6.4 billion litres (CSO, 2016). This increase in the volume of milk produced and processed, together with stringent measures on emissions from the industry is driving the need for innovative technological and operational solutions within the dairy processing industry.

When evaluating the sustainability of an industry, three aspects must be included, which are environmental, social and economic impacts. Life cycle assessment (LCA) is a useful tool for estimating the environmental impacts of the manufacture of dairy products. In addition, the main contributors to these emissions are highlighted within the analysis and its interpretation (for example, specific energy or resource consumption).

LCA has been used in studies of many major manufacturing countries of dairy products in order to evaluate the environmental and socio-economic impacts of the industry and its products as summarised by (Finnegan et al., 2015). However, a limited number of these studies consider the environmental impact of milk powder (Finnegan et al., 2015; Flysjö, 2012; Flysjö et al., 2014; Vergé et al., 2013) and butter (Djekic et al., 2014; Doublet et al., 2013; Finnegan et al., 2015; Flysjö, 2012; Flysjö et al., 2014; Nilsson et al., 2010; Sheane et al., 2011; Vergé et al., 2013) manufacture. In many of these studies, milk powder and butter have been included in an analysis of various dairy products. However, Nilsson et al. (2010) performed a comparative LCA of margarine and butter consumed in the UK, Germany and France. A cradle to factory gate boundary condition was used and a number of environmental impacts, including global warming potential, acidification potential and eutrophication potential, were estimated. Previously, Finnegan et al. (2015) estimated the global warming potential associated with the production of dairy products in the Republic of Ireland using country-level data. The analysis performed in this paper will build on this study by increasing accuracy, by using site specific data and including additional processes within the manufacture stage, as well as exploring additional environmental impacts of a number of post-farm dairy product life cycle stages. In order to determine the variability of the data used in an LCA and its effect on the results, an uncertainty analysis is used. A number of previous studies, including Aguirre-Villegas et al. (2012), Kim et al. (2013) and Broekema and Kramer (2014), employed Monte Carlo simulation to perform an uncertainty analysis.

The purpose of this study is to examine the environmental impact associated with manufacture of milk powder, which includes skim milk powder, whole milk powder and full fat milk powder, and butter in the Republic of Ireland using LCA. The results of this study are compared to similar European studies in order to benchmark Ireland's environmental performance for the manufacture of milk powder and butter. The results of this study identify the major contributors to the various impact categories. This information will be instrumental in identifying opportunities for reducing the environmental impact of the industry.

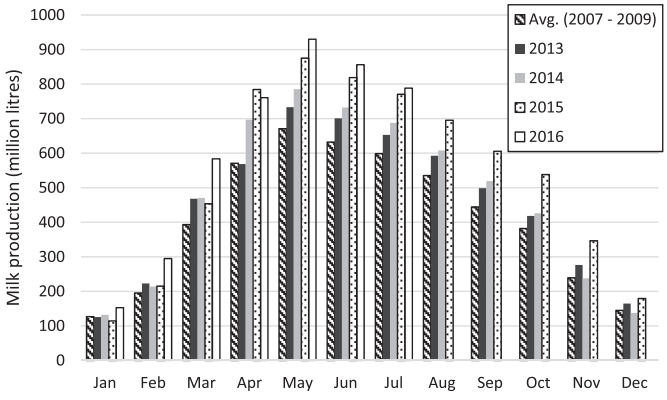

Fig. 1. Monthly milk production in the Republic of Ireland (source data: CSO (2016)).

2. Materials and methods

This study has been structured in accordance with the LCA guidelines of the International Organisation for Standardisation (ISO): ISO 14040 (ISO, 2006a) and ISO 14044 (ISO, 2006b). Furthermore, particular attention was paid to the LCA methodology for the dairy industry published by the International Dairy Federation (FIL-IDF, 2015). The FIL-IDF LCA methodology encompasses a number of existing standards and guidelines, including ISO 14040 (ISO, 2006a), ISO 14044 (ISO, 2006b), PAS2050 (BSI, 2011) and the Intergovernmental Panel on Climate Change (IPCC, 2007). The LCI data sets used in this study are based on site specific data, national data and the ecoinvent database Version 3 (Weidema et al., 2013), which is discussed further in Section 2.2. Both direct (on-site) and indirect (off-site) environmental impacts are included in the analysis using emission factors based on the ecoinvent database Version 3 (Weidema et al., 2013), which is discussed in greater detail in Section 3.1. The results of the analysis are compared to international studies in order to benchmark the environmental performance of the industry in Ireland, which is presented in Section 3.3.

2.1. Goal, scope and system boundaries of the study

The primary goal of this study is to perform an environmental LCA of milk powder and butter manufactured in the Republic of Ireland from farm gate to dairy processing factory gate. This assessment is performed in order to estimate the environmental impacts associated with butter and milk powder. The life cycle stages included within the system boundary of the study are raw milk transportation to the processing factory, processing of raw milk into each product and packaging of the final product. These processes are summarised graphically in Fig. 2. The

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