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Global warming potential associated with dairy products in the Republic of Ireland

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A B S T R A C T

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, an environmental life cycle assessment, which is performed in order to estimate the global warming potential (GWP) associated with 11 dairy products in the Republic of Ireland, is presented. The primary aim of the study is to examine the GWP associated with the processing of raw milk into the various products. However, the GWP contribution from dairy farms producing the raw milk is also included. Therefore, the system boundary utilised in this study is cradle-to-processing factory gate (dairy, farm, raw milk transportation and dairy processing). Furthermore, when performing the analysis, the 11 dairy products are clustered into 6 product groups: fluid milk (whole milk, skimmed and semi-skimmed milk); butter; cheese; cream; milk powders (buttermilk powders, whole milk powders, skimmed milk powders, and chocolate crumb); and whey powders (whey powders and proteins). The total GWP was calculated for each product group and mass allocation was used to derive the GWP of each product within that group. Data from 12 companies (18 dairy processing plants), which account for approximately 92% of the cow's milk processed in the Republic of Ireland, was used in this study to accurately assess the Irish dairy processing industry. From the analysis, it was found that raw milk production accounted for between 80.8% and 97.3% of the total GWP, depending on the amount of raw milk per kg of product. Additionally, raw milk transportation accounted for approximately 0.4% of the GWP, with the remainder contributed by the processing phase. The main contributor to GWP in the processing phase was direct energy use within the plant (electricity, natural gas and other fuel), which accounts for between 91 and 98% of the GWP, depending on the product. Furthermore, even though raw milk production is the most significant contributor to the total GWP of each dairy product, it was observed that energy use and water consumption in the processing phase were of the same magnitude as that of the production phase.

1. Introduction

With the world's population growing at a rate of over 1% per year, there is a constantly increasing demand for food. In 2015, the milk quota system that is in place in Europe is to be abolished, with an increase in milk production expected. However, if the European Union 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.

Ireland is one of Europe's largest producers of cows' milk with an annual production of over 5 billion litres (CSO, 2014) (Fig. 1). Currently, dairy ingredients and products comprise of almost 30% of the Irish food and drink export market.In 2013, dairy ingredients and products surpassed €3 billion for the first time, making it Ireland's largest indigenous industry (National Milk Agency, 2014). Approximately 10% of Ireland's milk is used for liquid milk consumption with the remainder made into a variety of products,

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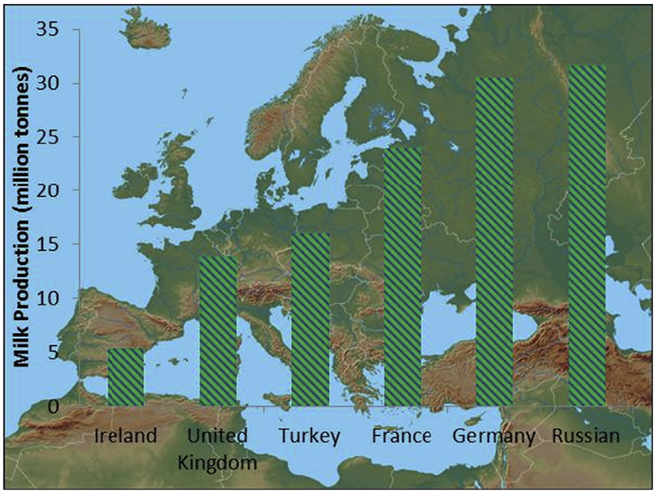

Fig. 1. Annual milk production of selected milk producing countries in Europe 2012 (Data obtained from: (DairyCo, 2015)).

including butter, cheese, milk powder, whey derivatives and proteins. The production values for dairy products manufactured in the Republic of Ireland in 2012 are given in Table 1.

Currently, the Republic of Ireland is on the brink of a new era for the dairy industry as quotas, which restrict milk production, are being abolished in 2015. As a result, milk production is expected to increase by 50% by 2020 (Farrelly et al., 2014). This increase in the volume of milk being processed, together 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. Life cycle assessment (LCA) provides a useful tool for estimating the greenhouse gas emissions associated with a particular product or service. In addition, the main contributors to these emissions are highlighted within the analysis and its interpretation (for example, specific energy or resource consumption).

Summaries of the findings from a large number of LCAs performed in order to estimate the global warming potential (GWP) of raw milk production worldwide are available in previously published literature. For example, Crosson et al. (2011) undertook a review of whole farm system models used in quantifying the greenhouse gas emissions relating to beef and dairy production. Yan et al. (2011) completed a review on milk and dairy production in a European context. Milani et al. (2011), Hagemann et al. (2011) and Fantin et al. (2012) have compiled a summary of the GWP of milk production from a large number of studies performed worldwide. These authors found that, typically, the GWP of milk production is between 0.8 and 1.4 kg CO_2eq kg^{-1} milk at the farm gate, where CO_2eq is carbon dioxide equivalent, which takes account of the GWP of greenhouse gases (carbon dioxide (CO_2), nitrogen oxide (N_2O) and methane (CH_4)) according to the weighting given by the IPCC (2007) guidelines for a time horizon of 100 years (i.e. GWPs of CO_2, N_2O and CH_4 are 1, 298 and 25, respectively). With regard to the Irish dairy sector, Casey and Holden (2005) have presented the carbon footprint for an average dairy farm unit. They found that the GWP of milk production in Ireland for the years between 1997 and 2001, for an economic allocation, between dairy, meat and crops production, was 1.3 kg CO_2eq kg^{-1} energy corrected milk (ECM) at the farm gate, where energy corrected milk (ECM) is defined as (Sjaunja et al., 1990):

$$ECM = Milk\,(kg) \times [383 \times fat(\%) + 242 \times protein(\%) + 165.4 \times lactose(\%) + 20.7]/3140 \quad (1)$$

However, Casey and Holden (2005) note that the value of the GWP estimated is affected by the method of allocation employed (no allocation, mass allocation or economic allocation) and the value varied between 1.3 and 1.5 kg CO_2eq kg^{-1} ECM. O'Brien et al. (2012) compares two research farms in order to explore the effects of seasonal grass-based and confinement dairy farms on GHG emissions. For seasonal grass-based dairy farms, which are the most common type of farm used in Ireland, the GHG emissions were found to be 0.8743 kg CO_2eq kg^{-1} fat and protein corrected milk (FPCM) at the farm gate, where FPCM is given by the formula:

$$FPCM = Milk\,(kg) \times [0.1226 \times fat(\%) + 0.0776 \times protein(\%) + 0.2534] \quad (2)$$

Additionally, O'Brien et al. (2014) estimated the carbon footprint of milk production on grass-based farms to be 1.11 kg CO_2eq kg^{-1} FPCM, which varied from 0.87 to 1.72 kg CO_2eq kg^{-1} FPCM, using data collected from 171 commercial Irish dairy farms. Upton et al. (2013) investigated the energy consumption on dairy farms in Ireland using a case study of 22 commercial dairy farms for 2011. The average energy consumption was found to be 2.37 MJ per kg of energy corrected milk at the farm gate. Furthermore, Murphy et al. (2014) explored the direct water use on 25 Irish dairy farms and found that approximately 6.4 L of water is used for every L of milk produced.

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. These countries include the USA (Kim et al., 2013; Nutter et al., 2013; Thoma et al., 2013), New Zealand (Flysjo, 2012), Canada (Vergé et al., 2013), Serbia (Djekic et al., 2014) and Portugal (González-García et al., 2012, 2013c, 2013b). Furthermore, Geraghty (2011) undertook a study in order to benchmark resource efficiency in Ireland's dairy processing sector. In this study, the energy and overall water consumption in 2009 of 15 dairy processing plants, that combined made up 94% of the dairy processing sector, was analysed. For the Irish dairy sector, the overall water consumption in dairy processing plants was estimated as 2.5 L per L of milk processed. A summary of studies published in the literature relating to environmental impacts of dairy processing plants is presented in Table 2. This builds on the summary presented by Djekic et al. (2014) for the dairy sector, but only presents studies relating to the processing of dairy products. Previously, the GWP associated the production and manufacture of dairy products in Ireland has

Table 1
Production values for dairy products manufactured in the Republic of Ireland in 2012

Dairy product	Tonnes ($\times 10^3$)	Share of Irish market (%)	Data source
Whole milk	310.9	27.5	CSO (2014)
Skimmed and Semi-skimmed milk	191.1	16.9	CSO (2014)
Butter	145	12.8	CSO (2014), IDB (2013)
Cheese (mostly cheddar)	185.1	16.4	CSO (2014)
Cream[a]	21	1.9	CSO (2014)
Buttermilk powder	15.7	1.4	CSO (2014), IDB (2013)
Whole milk powder	25.5	2.3	IDB (2013)
Skimmed milk powder	52.3	4.6	CSO (2014)
Proteins	44.9	4.0	IDB (2013)
Whey powder[a]	100	8.8	IFA (2012)
Chocolate crumb	39.9	3.5	IDB (2013)

[a] 2011 production statistic.