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ENVIRONMENTAL EVALUATION OF ONCE-A-DAY MILKING ON A PASTURE-BASED DAIRY SYSTEM IN NEW ZEALAND

Jeerasak Chobtang[1,2], Nicholas Sneddon[2], Sarah J. McLaren[1,2], Daniel Donaghy[2], Nicolas Lopez-Villalobos[2], Martin Correa Luna[2] and Stewart Ledgard[3]

[1] *New Zealand Life Cycle Management Centre,*
c/o Massey University, Private Bag 11222, Palmerston North 4410
[2] *SAE, Massey University, Private Bag 11222, Palmerston North 4410*
[3] *AgResearch, Ruakura Research Centre, 10 Bisley Road, Hamilton 3214*
Email: S.McLaren@massey.ac.nz

Abstract

Twice-a-day (TAD) milking is predominantly used in pasture-based dairy farming in New Zealand. However, once-a-day (OAD) milking is an alternative production system and is becoming more common among dairy farmers. The environmental impacts of OAD relative to TAD farming systems have not been examined to date, and this study used a cradle-to-farm gate Life Cycle Assessment (LCA) approach to quantify twelve environmental impact indicators for an OAD pasture-based dairy farm in the Manawatu. The functional unit was 1 kg of fat- and protein-corrected milk.

The results showed that the on-farm stage was the key hotspot in 10 out of 12 indicators (contributing > 50% to the total impacts). The off-farm contribution through the rearing of replacement animals was between 7% and 24% for the different impact categories. The off-farm contribution through brought-in feed was negligible (ranging from nil to 1% of the total impacts), due to low use of brought-in feed. The contribution of the manufacturing of agrichemicals (fertilizers and pesticides) was substantial for the impacts on ozone depletion (32% of the total impact), human toxicity-cancer (20%), particulate matter (11%), ionizing radiation (35%), and ecotoxicity for aquatic freshwater (27%). Transport of farm inputs for use on the farm accounted for 7% of the total impacts for the ozone depletion and ionizing radiation indicators.

The environmental profile of milk from the OAD case study farm compared favourably with the average environmental profile of both low and high intensity TAD dairy farms in the Waikato. However, this was at least partly due to the relatively low amount of brought-in farm inputs (in particular, brought-in feed). Further studies should be undertaken of other OAD farms in order to substantiate the conclusions of the present study.

Introduction

In New Zealand, dairy farming systems, which are based predominately on grazing pastures throughout the year (Moot et al., 2009), are becoming more diverse regarding farm management practices and the purposes of farming (Hickson et al., 2006; Stelwagen et al., 2013). In contrast to the common pasture-based dairy system where cows are normally milked twice-a-day (TAD), a once-a-day dairy farming system (OAD) where cows are milked only once over a 24-hour period throughout lactation or part of the lactation period (e.g. early lactation), is increasingly attractive to dairy farmers (Lembeye et al., 2016; Stelwagen et al., 2013). Indeed, the number of OAD farms has been increasing since the early 2000s (Bewsell et al., 2008; Grala et al., 2016; Edwards, 2018), and they accounted for approximately 5% of total dairy farms in New Zealand in the 2015/16 season (DairyNZ, 2016).

However, to date there has been no comprehensive evaluation of the environmental impacts of OAD dairy systems. Life Cycle Assessment (LCA) is a holistic approach used to comprehensively assess environmental performance (impacts) of a product system. The approach typically accounts for resource use and environmental emissions over the life cycle of a studied product (International Organization for Standardization, 2006a, b). The advantages of using LCA include: (i) identification of environmental-burden shifting from one life cycle stage to other life cycle stages, from one impact category to other impact categories and/or from one business to other businesses; and (ii) generation of multiple environmental impact indicators which decision-makers can use to identify and prioritize the most relevant and feasible improvement options to minimize environmental impacts of a product system (Hellweg and Milà i Canals, 2014).

In the present study, the cradle-to-farm gate life cycle environmental profile of a pasture-based OAD dairy farming system was assessed using an LCA modelling approach. The case study farm is located in Palmerston North, New Zealand. The farm transitioned from a TAD milking system in the 2012/13 dairy season to an OAD farming system in the 2013/14 dairy season. Over the two seasons (2013/14 and 2014/15) the animals were selected to suit the OAD system. The OAD system was fully implemented at the start of the evaluated production year of 2015/16. The farm is 117 effective ha in size running 262 cows. In addition, the farm operates as a low input system (DairyNZ, 2014) as it uses a small amount of brought-in inputs (e.g. chemical fertilisers and feed supplements) and has a low stocking rate (number of milking cows per hectare).

Methods

In the present study, multiple environmental indicators of the farm were assessed using an attributional LCA approach (Finnveden et al., 2009) and following the guidelines in the ISO 14040:2006 and 14044:2006 standards (International Organization for Standardization, 2006a, b). Additionally, dairy-specific LCA methods (e.g. functional unit and allocation method) recommended by the International Dairy Federation (2015) were adopted. All associated elementary flows were modelled using SimaPro v8 software (Pré Consultants, 2013), and elementary flows in the background system were taken from the ecoinvent v3.1 database (ecoinvent Centre, 2013).

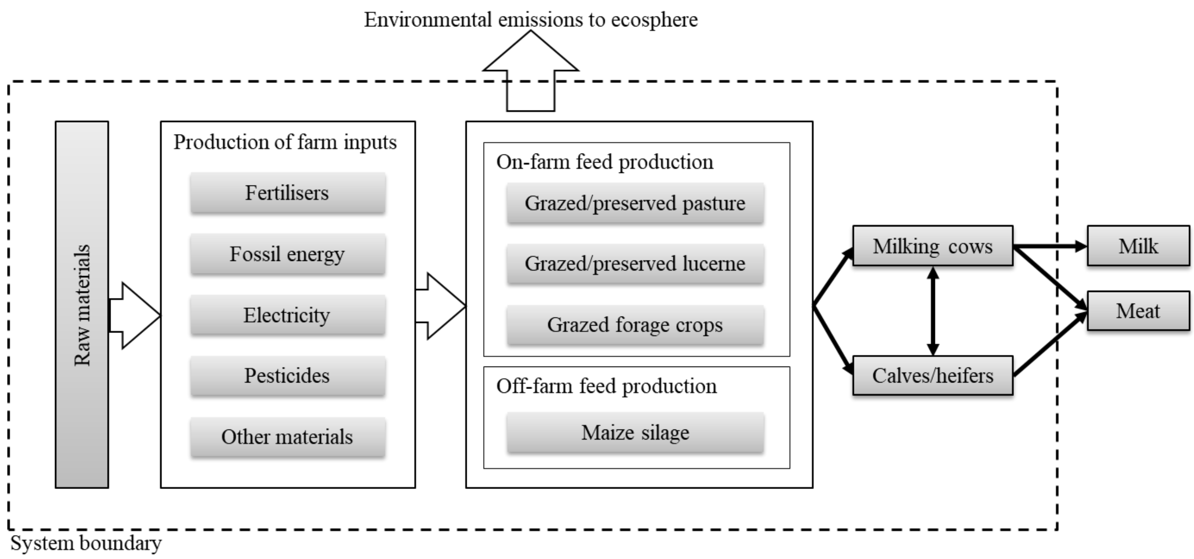
The functional unit was 1 kg of fat- and protein-corrected milk (FPCM). The calculation equation was based on a recommendation of the International Dairy Federation (2015): FPCM (kg) = milk yield (kg) × [0.2534 + (0.1266 × %fat) + (0.0776 × %true-protein)].

Partitioning environmental inputs and outputs between the co-products of milk and meat was carried out using a biophysical allocation method (i.e. energy requirements between milk and meat production). Environmental inputs and outputs from co-products in the off-farm stage and in the background processes (data derived from ecoinvent v3.1 database) were partitioned based on their 5-year-average economic values (revenues) as recommended for the cradle-to-farm gate life cycle of dairy production systems by the International Dairy Federation (2015).

The inventory methods and models associated with resource use and environmental emissions in the foreground processes (i.e. off- and on-farm stages) were the same as Chobtang et al. (2016). Total amounts of phosphorus (P) loss and nitrogen (N) leaching were quantified for this particular farm using the Overseer Nutrient Budget Model (Overseer, 2014) using local soil properties and local meteorological information (e.g. temperature and precipitation) in the model to calculate the losses of P and N.

All elementary flows, starting from acquisition of raw material through to milk production at the farm gate (the so-called cradle-to-farm gate perspective), were quantified. Figure 1 shows the main processes and system boundaries. The contribution of the farm infrastructure associated with off-farm and on-farm stages (e.g. farm shed, road, fence, farm machine and animal medicines) was not accounted for in the present study, due to lack of accurate data and appropriate inventory models.

Figure 1. Simplified elementary flows and cradle-to-farm gate system boundary for the farm.



Results

Environmental impact profiles (per kg FPCM) for the case study farm are presented in Table 1. The average environmental impacts (per kg FPCM), based on 14 farms at a low intensification level and 14 farms at a high intensification level, for farming systems in the Waikato region (Chobtang et al., 2017) are also given in Table 1. It should be noted that these farms were in a different region with higher rainfall (c. 1300 mm/year) on free-draining volcanic soil and higher pasture production, with different nutrient loss risk to the case study farm. Nevertheless, they provided detailed data collected using the same LCA methods.

Most environmental indicator results in the OAD farming system were >20% lower than those in both the low and high intensification level farming systems (indicated by red in Table 1). The exceptions were for the climate change, ozone depletion, photochemical ozone formation, acidification, terrestrial eutrophication, and marine eutrophication indicator results at the low intensification level, and the marine eutrophication indicator result at the high intensification level where the differences were within ±20% of the case study farm results (indicated by yellow in Table 1).

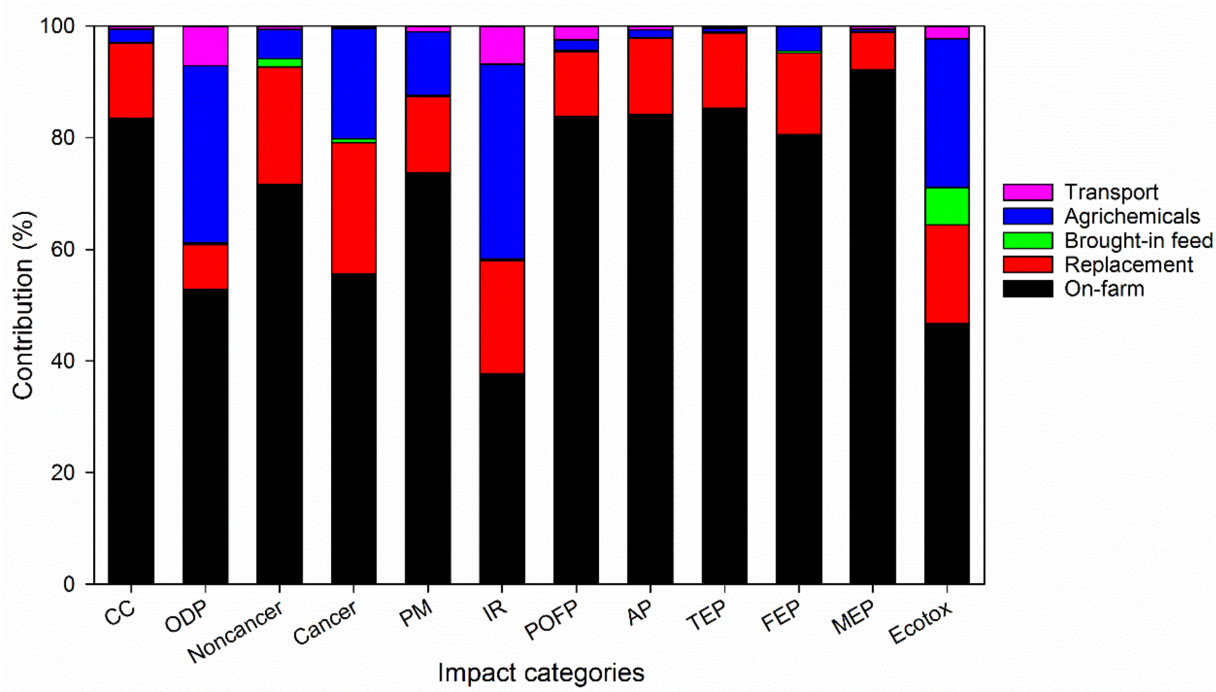
Table 1. Environmental profiles of the case study farm *versus* the low and high intensification level dairy farming systems in the Waikato region (Chobtang et al., 2017).

Impact category	Unit	Case study farm	Low intensification	High intensification
Climate change	kg CO_2 eq.	0.66E+00	+11	+30
Ozone depletion	kg CFC-11 eq.	0.88E-08	-2	+32
Human toxicity, non-cancer effects	CTU_h	0.30E-07	+800	+783
Human toxicity, cancer effects	CTU_h	0.12E-08	+742	+792
Particulate matter	kg $PM_{2.5}$ eq.	3.11E-04	+26	+63
Ionizing radiation (human health effects)	kBq U^{235} eq.	0.33E-02	+170	+276
Photochemical ozone formation	kg NMVOC eq.	2.29E-03	+1	+24
Acidification	molc H^+ eq.	1.20E-02	+13	+37
Terrestrial eutrophication	molc N eq.	5.33E-02	+9	+31
Freshwater eutrophication	kg P eq.	0.67E-04	+36	+61
Marine eutrophication	kg N eq.	2.94E-03	-20	+1
Freshwater ecotoxicity	CTU_e	0.15E+00	+647	+893

[a] CO_2 = carbon dioxide; eq. = equivalent; CFC-11 = trichlorofluoro-methane; CTU_h = comparative toxic unit for humans; $PM_{2.5}$ = particulate matter less than 2.5 μ in diameter; kBq = kilobecquerel; U^{235} = uranium-235; NMVOC = non-methane volatile organic compounds; molc = mole of charge; H^+ = hydrogen ion; N = nitrogen; P = phosphorus; CTU_e = comparative toxic unit for ecosystems. Note that **Yellow** = the difference between Chobtang et al. (2017) and the case study were within a range of ±20%; and Red = the impact indicator results in Chobtang et al. (2017) were more than 20% worse than the case study.

The relative contributions of individual life cycle stages to each impact category for the case study farm are depicted in Figure 2. The on-farm stage made the largest contribution to most impact categories, ranging from 38% to 92% of the total impacts. The contributions of the rearing of replacement animals and manufacturing of agrichemicals (e.g. fertilisers and pesticides) were also significant, ranging from 7% to 24% and 1% to 35% of the total impacts, respectively. In contrast, the contribution of brought-in feed (i.e. maize silage) was insignificant for all impact categories except freshwater ecotoxicity (Ecotox). Similarly, the contribution of transport of off-farm inputs for use on a dairy farm was not substantial, except for the impacts on ozone depletion and ionizing radiation where it accounted for 7% of the total impacts.

Figure 2. Relative contribution of life cycle stage to impact category results in the cradle-to-farm gate life cycle of the case study farm.



Discussion and conclusions

The present study generated the first environmental profile of an OAD dairy farming system. Multiple environmental impact indicators were assessed using an attributional LCA approach. The results showed that the on-farm stage was the key hotspot in 10 out of 12 indicators (contributing > 50% to the total impacts). Overall, the results were lower than the average environmental profile of both low and high intensity TAD dairy farms in the Waikato. However, this was at least partly due to the relatively low amount of brought-in farm inputs (in particular, brought-in feed). Therefore, further studies should be undertaken of other OAD farms in order to substantiate the conclusions of this study.

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