2. Dairy Production

112. Allocation choices strongly affect technology evaluation in dairy processing

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ABSTRACT
This paper illustrates how different allocation approaches affect the assessment of energy and water saving technology options in the dairy processing sector. The choice between allocation on facility level or process level was evaluated, as well as the choice between dry matter and economic allocation in a case study of a mozzarella facility based on primary data. It was found that the carbon footprint allocated to the main product, mozzarella, is very sensitive to these methodological choices, because the dry matter in mozzarella is valued relatively highly, and would receive impact from the energy intensive whey processing under the facility level allocation approach. Economic allocation on the process level gives results that are most unambiguous and straightforward to interpret in the specific decision context of technology options evaluation.

Keywords: Mozzarella, Whey, Dairy, Global Warming Potential, Multifunctionality

1. Introduction

In the dairy processing sector, saving energy and water use through developing and integrating different innovations is an important priority. Such innovations are being piloted in the EnReMilk project (an EC Framework Programme 7 project) in a German dairy facility that produces among others skim milk powder, and an Italian mozzarella facility. To support decisions on the selection of innovations from the EnReMilk project in these distinct facilities, Life Cycle Assessment (LCA) is considered as the most appropriate methodology. Environmental footprinting, i.e. calculating LCA impacts for distinct products, is gaining popularity because it provides easy-to-understand impact indicators that can be added up (Ridoutt and Pfister 2013). Companies, consumers and governments often take a simple choice oriented comparison mindset in which it is hard to consider external consequences of this choice. In the current decision context, external consequences outside the dairy processing facility, caused via market mechanisms, are not expected.

Although LCA studies are generally done according to the ISO-standards 14040 and 14044 (ISO Technical Committee ISO/TC 207 2006a,b), these standards leave several methodological choices up to the practitioner, which can strongly affect the results of the assessment (among others Yan et al. 2011, Kim et al. 2013). Among these choices, the approach for dealing with multifunctionality is an important point of attention in dairy processing. Multifunctionality arises in cheese production in the curd-whey separation, milk-cream separation, the milk-beef farming system and the feed-seed oil production system (Feitz, Lundie, Dennien, Morain, & Jones, 2007; Thoma, Jolliet, & Wang, 2013; Thomassen, Dalgaard, Heijungs, & de Boer, 2008; Tucker et al., 2010) and is an important methodological point of attention. How multifunctionality should be treated seems to become increasingly consistent, when considering the scientific and industrial guidance (Feitz et al. 2007, Aguirre-Villegas et al. 2012, European Dairy Association et al. 2015, IDF (International Dairy Federation) 2015).

Approaches that deal with the multifunctionality problem through allocation are relevant in the case of cheese, because avoiding allocation approaches (as recommended by ISO Technical Committee ISO/TC 207 (2006b)) cannot fully solve the problem in this case: Subdivision is not possible since the curd/whey separation reflects a chemical separation of milk; and Substitution is not possible because there is no realistic market-average alternative to producing ricotta, nor can a hypothetical alternative be considered that does not originate from the multifunctional process of curdling milk (Aguirre-Villegas et al. 2012).

In this paper, it will be evaluated in which way different allocation approaches affect the results of an LCA for a specific mozzarella producing facility. These findings will be discussed in the context of the application of the LCA, and critically reviewed in a broader context.

2. Methods

Goal and Scope: Since this paper aims to illustrate the effects of different allocation approaches, the global warming potential was used as a straight-forward and suitable indicator for the goal of this paper. Because the LCAs conducted in the EnReMilk project itself have a broader focus, these evaluate all impact categories from ReCiPe 2008 (Goedkoop et al. 2009). The functional unit has been defined as “1 kg of mozzarella for pizza applications at the gate of the mozzarella facility in the baseline year 2014”. The system boundaries of the overall LCA are from the cradle to the gate of the mozzarella facility, and all material inputs, consumables and capital goods have been included except office activities, facilities overhead and supporting services because these were estimated to contribute less than 1% of the total global warming potential.

Production description: Raw Milk is stored after delivery and pasteurized, and subsequently standardized by separating a small share of the milk fat (cream) from the raw milk. The standardized milk is curdled by addition of a bacterial starter culture and rennet in the substeps of pre-ripening, coagulation and curd cutting. The resulting (sweet) whey is drained and collected, and the curd left to ripen, from which additional (acid) whey is collected. Mozzarella is shaped from the ripened curd by a process of cutting, stretching and molding. The cylinder or ball shaped mozzarella is pre-cooled with water, cooled with ice water, and packaged for subsequent storage. Ricotta is produced through heating the sweet whey. Furthermore, cream is churned into butter. A complete picture with all main product and byproduct flows is shown in Figure 1.

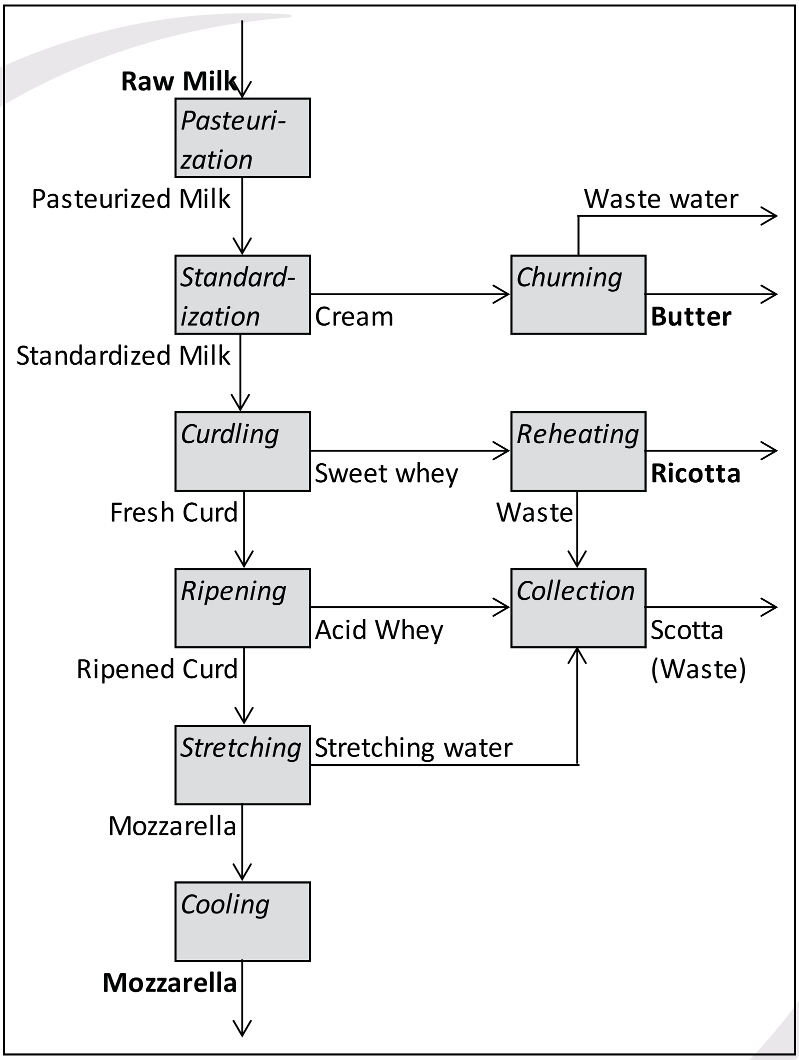

Figure 1: Overview of Mozzarella processing steps, excluding packaging

The remaining, protein-poor whey is combined with the acid whey and the waste water from mozzarella stretching. This combination of byproducts is called scotta, is sent off-site for waste treatment. Wastewater results from (pre-)cooling the mozzarella, butter production and from rinsing and cleaning equipment. Ice water cooling consumes significant amounts of electricity, whereas all other process steps consume much small amounts of electricity. Steam is consumed only during pasteurization, cleaning-in-place and mozzarella stretching, and water is consumed during pre-cooling and packaging.

Data Collection: Steam, electricity and water consumptions in the mozzarella facility were collected on the unit process level. This is possible because a monitoring system is being set up to evaluate the facility performance in different experimental technology pilots in the EnReMilk project. In addition to the baseline case of the mozzarella facility, a hypothetical scenario of moving from production of ricotta to whey powder was selected to illustrate the consequences of all four allocation approaches in an extreme case. The whey drying process was modelled using data from the skim milk powder facility in Germany, collected in the EnReMilk project. The selected facility data is representative for a typical day of production, excluding situations of intensive production or production problems. On a typical day, the mozzarella facility consumes 21 tons of milk and produces 3 tons of cow milk-based mozzarella cheese for pizza application, which is called fior di latte in Italy. As such, the facility has a limited size compared to cheese production facilities in the US (Aguirre-Villegas et al. 2012, Kim et al. 2013).

The impact of raw milk was derived from the Agri-footprint database, using economic allocation (Blonk Agri-footprint bv. 2014a, b). EcoInvent 3.2 processes (Weidema et al. 2013) were used to model the impact of electricity, steam, cleaning in place, waste water treatment and transport, augmented with specific grid mix from the International Energy Agency (IEA) (2014) and through personal interaction with the facility owner. Packaging of the final mozzarella product was included by following the draft PEFCR for Dairy (European Dairy Association et al. 2015) and including packaging raw materials from EcoInvent 3.2. SimaPro 8.2 was used for composing the model and extracting the results (Pré Consultants 2016).

Allocation: As discussed in the introduction, different allocation approaches can be identified. Firstly, the facility can be regarded as a whole with a total resource consumption (facility level, FL) or it can be subdivided into groups of unit processes that relate to all, a subset or one of the final products (process level, PL), as illustrated in Figure 2.

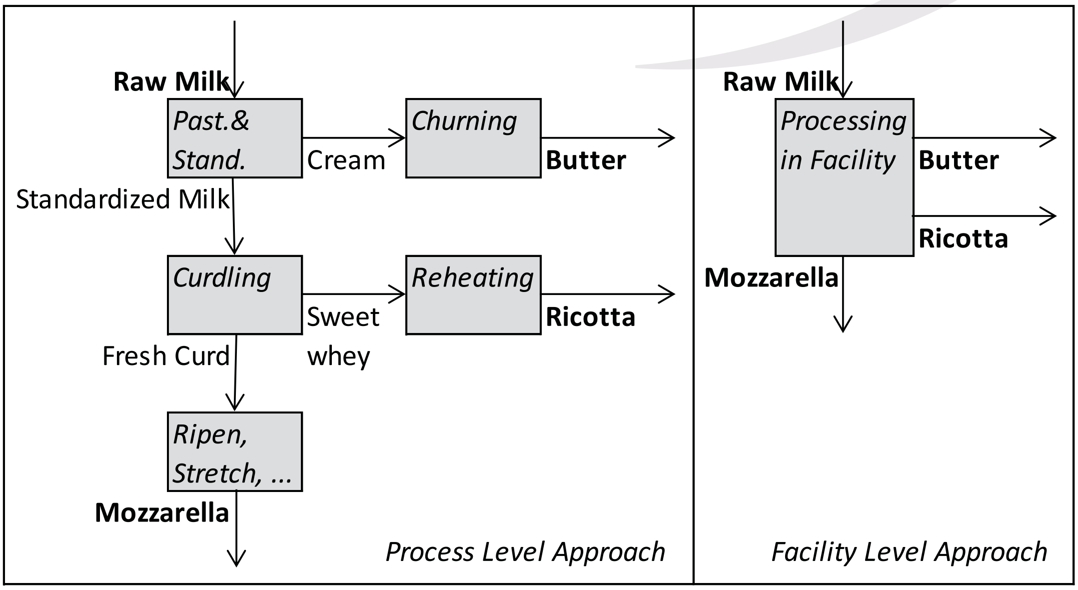

Figure 2: Two different allocation approaches for a mozzarella producing facility: on the left the process level approach, on the right the facility level approach. The distinction between dry matter allocation and economic allocation is not shown in this figure.

In the facility level approach, all impact is allocated between mozzarella, ricotta and butter. In contrast, two allocations are done in the process level approach: the impact upstream of the standardization is allocated between standardized milk and cream, and the impact upstream of curdling is allocated between sweet whey and fresh curd. Secondly, allocation between multiple flows from a process can be done according to dry matter content of the flows (dry matter allocation, DMA) or to the revenue generated with these flows (economic allocation, EA). Dry matter content data of all products were reported by the facility owner, as well as market prices of the final products. Market prices of intermediate products were derived from prices of raw milk and of the final products. These two choices lead to four allocation approaches.

3. Results

In Figure 3 the effects of the different allocation approaches can be seen for the entire cradle-to-gate assessment. It is clear that the raw milk production has the largest contribution with 61-77%, and that transport is the secondary contribution with 15-19% for all allocation approaches, when considering the baseline case (ricotta production). Figure 3 shows that less impact is allocated to mozzarella under dry matter allocation compared to economic allocation, for both facility and process level approaches, because mozzarella has a larger share in the total revenue than in the total dry matter utilized from the milk. The process level approach leads to a lower impact compared to the FL approach under DMA, because the allocation ratio between curd and sweet whey are different from the allocation ratio between mozzarella and ricotta. This is because curd and whey still include milk solids that ultimately go to waste (scotta), and could be corrected by only including the dry matter that is not wasted in the allocation factor calculation for curd and whey.

Under the dry matter facility level approach, the change in sweet whey processing (from ricotta to whey powder production) reduces the impact of mozzarella because the milk solids utilization has increased. On the other hand, under the dry matter process level approach, the mozzarella impact stays the same, because sweet whey processing is separated in the model. Under the economic allocation approaches on both levels, the change from ricotta to whey powder increases the impact of mozzarella, because less revenue is achieved by producing whey powder compared to ricotta.

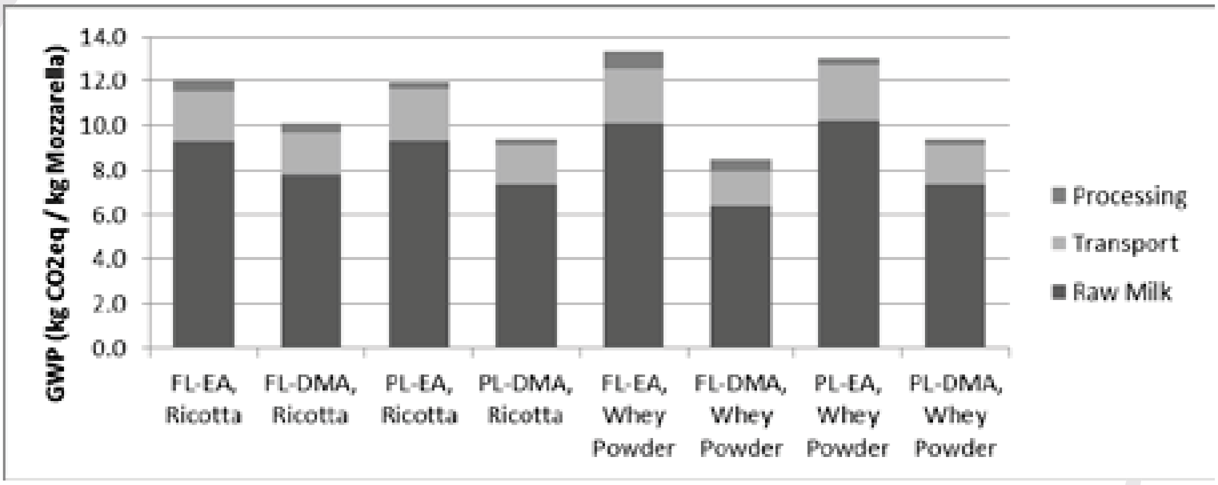

Figure 3: Cradle-to-gate carbon footprints (kg CO2eq/kg of product) of mozzarella with contributions of raw milk, transport and processing, under different allocation approaches (FL=Facility level, PL=Process level, EA=Economic allocation, DMA=Dry matter allocation) for two scenarios: producing ricotta from sweet whey and producing whey powder from sweet whey

The contribution from the processing step is limited, compared to raw milk impacts and transport, but is affected by technological innovations within the dairy facility. For technology evaluation, it is specifically interesting how the impact of processing is distributed over the different products. As shown in Figure 4, mozzarella receives a larger share under economic allocation compared to dry matter allocation, because mozzarella has a larger share in the total revenue than in the total dry matter utilized from the milk. Mozzarella receives a much smaller share of the processing impact in the process level approaches, because the large energy consumption in ricotta is more correctly attributed to the ricotta process, compared to the facility level approaches. The hypothetical change from ricotta to sweet whey production increases the total processing impact by 47%. Because this increase strongly affects the mozzarella contribution under the facility level approaches, the mozzarella impact is made strongly dependent on whether ricotta or whey powder is produced. The effect is most strong for economic allocation, because whey powder provides less revenue, while it increases dry matter utilization in dry matter allocation.

The effects of the trends described above translates into highly variable carbon footprints of individual products, as shown in Table 1. Mozzarella receives high impacts under facility level approaches, while whey products receive higher impacts under process level approaches, especially under dry matter allocation.

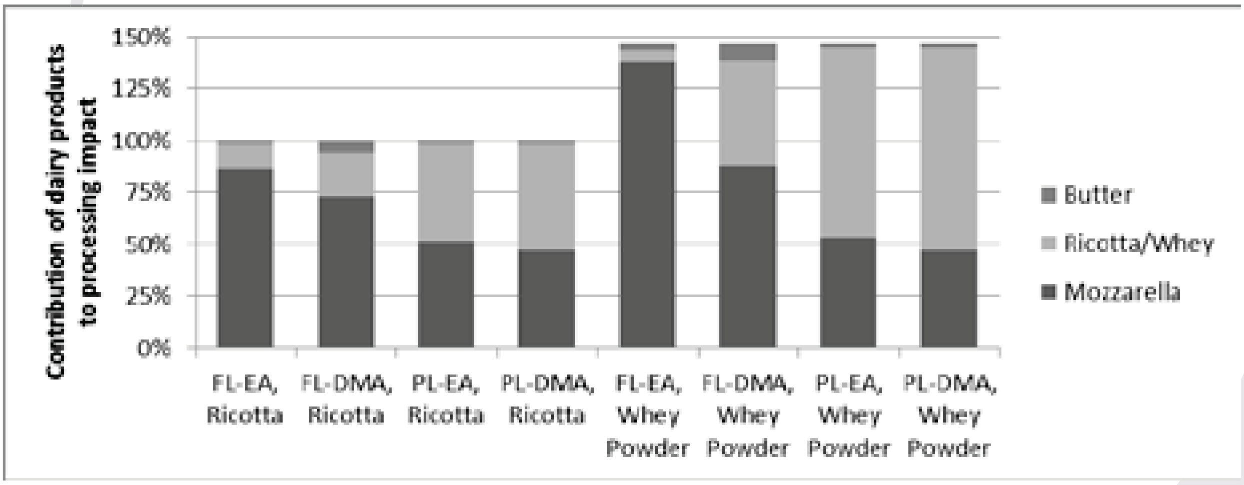

Figure 4: Percentage contributions of the products mozzarella, ricotta or whey, and butter, to the processing impact under the different allocation approaches, for the two scenarios. All data is relative to the impact of the ricotta scenario, so that the whey powder scenarios have a higher total impact.

Table 1: Carbon Footprints (kg CO2eq/kg of product) of the processing step in the mozzarella facilities under the different allocation approaches, for the two scenarios

	Scenario:	**Producing Ricotta**			**Producing Whey Powder**	
Allocation Approaches		*FL*	*PL*		*FL*	*PL*
EA	**Mozzarella**	**0.48**	**0.28**	**Mozzarella**	**0.76**	**0.29**
	Ricotta	0.15	0.60	Whey Powder	0.12	1.91
	Butter	0.25	0.20	Butter	0.39	0.20
DMA	**Mozzarella**	**0.40**	**0.26**	**Mozzarella**	**0.48**	**0.26**
	Ricotta	0.27	0.65	Whey Powder	1.07	2.04
	Butter	0.80	0.20	Butter	0.96	0.20

4. Discussion

The results show that different allocation approaches affect both the contributions upstream of the processing facility and the impact of the processing.

The process level approach correctly separates the considerations on how much energy to invest in whey processing from the mozzarella production, since a significant change in the whey processing does not affect the mozzarella production economically or physically. The facility level approach attributes some of the impact from whey processing to mozzarella. Combined with dry matter allocation this could give the perverse incentive of moving to whey powder production, in which more energy is consumed. The process level approach gives relevant information in the decision context of technology evaluation, so that the additional detail and effort could be justified (Ekvall and Finnveden 2001). Furthermore this subdivision is recommended by the ISO standard 14040.

However, the process level approach is only possible under high data availability. Although intensive contact with facility owners and technical experts is possible in the EnReMilk project, it turned out to be challenging to be completely certain of the mass and dry matter balances that were needed to achieve the highest possible reliability. It was noted before that it can be challenging to account for all resource uses on a process level (Ekvall and Finnveden 2001), and hybrid approaches have been proposed (IDF (International Dairy Federation) 2015). The impact of the same products from facilities with different product portfolios will be most comparable if these facilities use the process level approach. However, if facilities with lower data availability are not able to follow the process level approach, all facilities should use the facility level approach , because using different allocation approaches would make results even less comparable.

For technology evaluation, the process level approach is preferred, because they give better consistency for all products and comparability between different technology alternatives. In a scientific context, the unavailability of data is a bad argument to say that the data does not need to be collected, but when footprinting products from several businesses such practical considerations play a larger role. Thus, a trade-off can be recognized between, on the zone hand, the benefits of internal comparability and consistency in the process level approach, and the practicality and external comparability in the facility level approach on the other hand.

The choice between dry matter and economic allocation approaches is more fundamental. While a causal relationship between the allocation property and the inputs of the multifunctional process is recommended (ISO Technical Committee ISO/TC 207 2006b), a causal relationship between the allocation property and the incentive to produce a product is also thinkable. Examples of incentives are generating revenue, nourishing people, etc., with properties like price, nutrient content and energy value. Economic allocation is criticized because prices of dairy products are variable and would introduce variability in economic allocation factors across time and regions (Feitz et al. 2007, Aguirre-Villegas et al. 2012). The variation in prices translates to variation in production incentives, which in fact should be addressed by using market-standardized price averages over several years. Dry matter allocation approaches follow the physical flows throughout the facility, and is more practical in dairy processing, because price information is not required and dry matter tracking is common in the industry (Aguirre-Villegas et al. 2012).

Considering these prior observations as well as the decision context of the dairy facility, which is essentially economic, economic allocation is preferred. The dry matter approach is not entirely consistent in this context, because it is influenced by the share of milk solids that is wasted. Since waste is produced when it is economically unattractive to turn a process flow into a valuable product, economic considerations are introduced in the dry matter approach. Furthermore, the implied causal link between the dry matter content and the environmental impact, is only valid for the raw milk impacts, but not for the processing impacts. Economic allocation is more practical in this context because prices vary less on the Italian mozzarella market than globally. Using averaged prices also matches the allocation with the time frames of decision context for technological innovations and other production changes.

For technology option evaluation, the product perspective is useful, because a producer is most rewarded by improving the impact of the main product. The total environmental impact of the product portfolio (1kg mozzarella plus the accompanying whey product and butter) will be an additional useful perspective, because it illustrates the total change from one technology to another, and excludes the high sensitivity to allocation. Figure 4 provides an illustration of this.

The process level approach may be valuable for replication in other production systems, in which byproduct flows separate from the main product flow early in the processing facility, or require large energy use in byproduct processing. Examples are whey processing (Aguirre-Villegas et al. 2012), drying of byproducts from sugar production or from wet milling wheat grain, and drying brewers grains from beer brewing.

5. Conclusions

This paper evaluated how different allocation approaches affect the results of an LCA for a specific mozzarella producing facility. The process level approach provides useful detail that clarifies the incentives for a producer to improve processes that are specific to each coproduct: Improving processes in mozzarella production accurately benefits the mozzarella impact, and the same is true for whey processing. Economic allocation relates incentives for production to the different coproducts while dry matter allocation also includes economic considerations through the definition of waste. The different allocation approaches may result in different technology preferences. In the evaluation of technology options in one dairy facility, process level economic allocation was found most unambiguous and straightforward to interpret. Although a growing consensus on allocation may be recognized for footprinting in the developments of industry guidelines, the goal and context of different LCA studies may best be served with different allocation approaches. The ISO standard and scientific papers can be interpreted from different angles, which allows for these different approaches. This indicates that the debate on allocation is not likely to be finished.

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