Influence of site conditions and production system on the environmental impacts of domestic and imported cheese

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ABSTRACT

In this study, cheese produced in Switzerland was compared to imported cheese from the main countries of origin, France, Italy, and Germany. The environmental impacts of cheese production were dominated by milk production. The average Swiss milk production was characterized by a low input of concentrates and the lowest milk yield per cow. Despite this lower milk yield, the environmental impacts of Swiss milk were lower or similar to milk produced in the other countries, with the exception of land occupation. The good growing conditions for grassland and a high quality of roughage allow to produce milk at moderate intensity level in an efficient way. The study showed that there is no simple relationship between the amount of concentrates, milk yield and environmental impacts, instead the results depend on the whole production system, and site conditions can influence the environmental impacts significantly.

Keywords: milk, cheese, imports, concentrate feed, milk yield

1. Introduction

1.1. Background

Milk is the most important product of Swiss agriculture and also dominates its environmental impacts. In 2012, 21 % of the total agricultural production value in Switzerland was generated with milk (BLW 2013). Only 12 % of Swiss milk was directly consumed, whereas 42 % was transformed to cheese (BLW 2013). Since 2007, a free-trade agreement is effective between Switzerland and the EU, leading to increased imports and exports of cheese in Switzerland. In an effort to ensure the future ability of Swiss agricultural products to compete with those from abroad, the food industry, supported by the Federal Government, has developed a quality strategy aimed at setting the environmental and quality credentials of Swiss farm products apart from those of other countries. There is, however, a shortage of data which would allow a systematic and scientifically sound comparison of the environmental impact of foodstuffs from different countries of origin. Furthermore, production conditions as well as the production systems within a country vary widely. For a sound decision making on how to improve the environmental impacts of Swiss products, there is a need for reliable and comparable data on the environmental impacts of agricultural products originating from different countries.

1.2. Goal and scope definition

The aim of this study was to generate inventories of cheese produced in Switzerland and abroad, and to compare the environmental impacts of Swiss and imported cheese. Cheese produced in Switzerland was compared to cheese from the main countries of origin, France, Italy, and Germany. The Swiss production was differentiated according to the region (lowlands, hills, and mountains) and to the production system (grassland based with barn feeding, full grazing system and high-yielding system with higher concentrate input). To be able to distinguish between differences in the agricultural production and differences occurring in downstream stages (e.g. different transport distances), life-cycle-analyses were conducted both at the farm gate and at the point of sale. For the comparison at the farm gate and at the point of sale the functional units were 1 kg milk and 1 kg of cheese, respectively.

2. Methods

The environmental impact of the products investigated was determined using SALCA (Swiss Agricultural Life Cycle Assessment; Nemecek et al. 2010), the life cycle assessment method developed by Agroscope. SAL-CA comprises a life cycle inventory database for agriculture, models for direct field and farm emissions, a choice of methods for impact assessment, calculation tools for farming systems (farm and crop level), an evalua-tion concept, and a communication concept for the results.

The following environmental impacts were examined: non-renewable energy demand, global warming potential, ozone formation potential, demand for phosphorus and potassium resources, land competition, deforestation, water use WSI (water use in m^3 weighted with a “water stress index” which takes account of water scarcity in the different countries), eutrophication potential, acidification potential, terrestrial ecotoxicity potential, aquatic ecotoxicity potential and human toxicity potential. The impact assessment methods used as well as the models used to calculate direct emissions are described in Nemecek et al. (2010). A rating system was used to assess the differences in individual results. It was not possible to examine the environmental impact of soil quality or biodiversity due to a lack of the required data. The differences between the impacts were evaluated by assessment classes, which differed among the impact categories.

2.1. System boundaries

For the agricultural production, all on-farm activities and external inputs (e.g. feedstuff, diesel, mineral fertilizers) for milk production were considered, as well as the necessary infrastructure (buildings and machinery) and the usable agricultural area needed (Figure 1, A).

For cheese production, additionally to milk production transports to the cheese dairy, processing and transports to the point of sale in Switzerland were considered (Figure 1, B). Cheese processing generally took place in the country of origin and the finished cheese was transported to the point of sale in Switzerland.

2.2. Production inventories

The Swiss milk production systems were derived from model farms of a former project (Hersener et al., 2011) and refer to an average Swiss production. The foreign inventories were newly created on the basis of the Swiss systems, the most important key figures for livestock production being adapted to the specific country. If no data were available, Swiss data were extrapolated on the basis of the number of dairy cows. Table 1 shows an overview of the most important production inventories of the specific countries. The Swiss data represent a national average; the foreign systems refer to the most important production systems (typical) within the country under consideration.

An economic allocation was conducted between milk and meat. 87 % of the inputs were allocated to milk production and 13 % to meat production. In order to ensure comparability, Swiss data were used also for the foreign systems. Background data were derived from the SALCA database (Nemecek et al., 2010) and ecoinvent V2.2 (ecoinvent Centre, 2010).

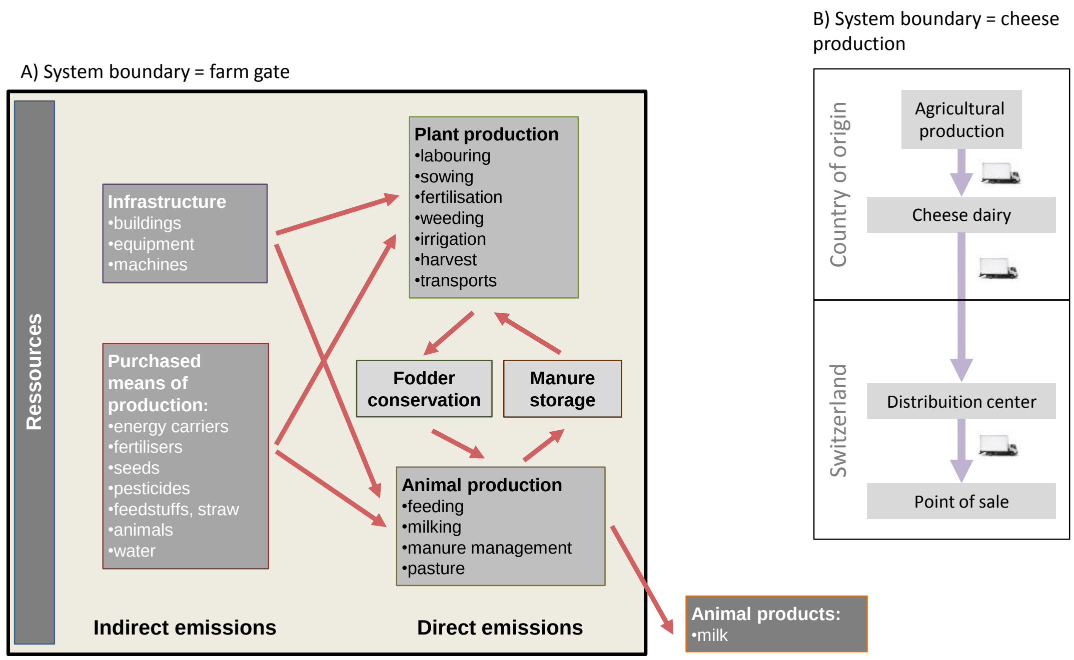

Figure 1. System boundaries for agricultural production (A) and cheese production (B)

Table 1. Production parameters of the milk production systems in Switzerland (Milk CH), Germany (Typ. Milk DE), France (Typ. Milk FR) and Italy (Typ. Milk IT). DM: dry matter, FM: forage mixture, BR: basic ration. Typ. = typical.

Parameter	*Unit*	Milk CH	Typ. Milk DE	Typ. Milk FR	Typ. Milk IT
Number of dairy cows		19.9	80	46	419
Age of first calving	*months*		28	29	27
Useful life	*months*	40	37.7	32.9	21
Restocking	*%*	30	36	37	37
Calves born alive	*calves*year^{-1}*	0.9	0.9	0.83	0.9
Barn arrangement		50% free stall barn	50% free stall barn	100% free stall barn	100% free stall barn
Milk yield	*kg*cow^{-1}*year^{-1}*	6,800	8,000	8,200	9,450
Milk production	*kg*farm^{-1}*year^{-1}*	127,372	600,000	369,000	3,721,026
UAA for milk production	*ha*	0.58	0.6	0.84	0.51
Pasturing	*days*year^{-1}*	167	-	112	-
Feed intake	*kg DM*cow^{-1}*day^{-1}*	20.2	19.6	20.4	18.0
Concentrates	*kg DM*LU^{-1}*year^{-1}*	877 *25% FM dairy* *75% FM cereal*	2,019 *33% wheat* *33% barley* *25% soya* *8% rape meal*	2,164 *47% soy meal* *41% wheat* *8% FM conc.* *4% FM min.*	2,498 *35% maize flour* *23% soy meal* *15% cotton seed* *13% protein supp.* *10% soy seeds* *4% maize flakes*
Basic ration	*kg DM*LU^{-1}*year^{-1}*	6,752 *41% grass silage* *29% grass* *19% hay* *11% maize silage*	5,100 *56% grass silage* *37% maize silage* *12% hay*	5,804 *62% maize silage* *26% grass* *9% grass silage* *3% hay*	4,068 *60% maize silage* *39% hay* *1 % grass*
Share of basic ration in total ration	%	89	72	76	62

2.3. Downstream processes

For all systems analyzed, data about cheese production were derived from Schmid et al. (2010). The cheese dairy in this study represents the average cheese production in artisanal dairies in Switzerland. Due to the lack of more country-specific data, this data was also used for the foreign systems; only the electricity mix was adapted to the country in question. An economic allocation between cheese and its by-products (whey) was carried out at which 85 % of the environmental impacts were allocated to cheese.

For the transports, average transport distances from the most important milk producing regions of each country (after Hemme et al., 2011) were considered. Table 2 shows an overview of the means of transport and transport distances assumed.

Table 2. Means of transport and transport distances for Swiss and imported cheese

Country of origin, route of transport	Means of transport	Distance (km)
Switzerland		
Farm – cheese dairy (milk)	lorry 3.5-20 t, fleet average Switzerland, refrigerated	20 [1)]
Cheese dairy – distribution center (cheese)	lorry 20-28 t, fleet average Switzerland, refrigerated	100 [2)]
Distribution center – point of sale (cheese)	lorry 3.5-20 t, fleet average Switzerland, refrigerated	25 [2)]
Germany		
Farm – cheese dairy (milk)	lorry >16 t, fleet average Europe, refrigerated	150 [3)]
Cheese dairy – distribution center (cheese)	lorry >16 t, fleet average Europe, refrigerated	650 [4)]
Distribution center – point of sale (cheese)	lorry 3.5-20 t, fleet average Switzerland, refrigerated	25 [2)]
France		
Farm – cheese dairy (milk)	lorry >16 t, fleet average Europe, refrigerated	150 [5)]
Cheese dairy – distribution center (cheese)	lorry >16 t, fleet average Europe, refrigerated	800 [4)]
Distribution center – point of sale (cheese)	lorry 3.5-20 t, fleet average Switzerland, refrigerated	25 [2)]
Italy		
Farm – cheese dairy (milk)	lorry >16 t, fleet average Europe, refrigerated	150 [5)]
Cheese dairy – distribution center (cheese)	lorry >16 t, fleet average Europe, refrigerated	400 [4)]
Distribution center – point of sale (cheese)	lorry 3.5-20 t, fleet average Switzerland, refrigerated	25 [2)]

Sources: [1)]Schmid (2010); [2)]Alig et al. (2012) [3)]Reinhard et al. (2009); [4)]Own estimation (Google Maps), based on main production regions according to Hemme (2011); [5)]Assumption: as in Germany

3. Results

3.1. Agricultural production

At farm gate level Swiss milk production generally scored more favorably or was within the same range as milk production abroad. The only exception was land competition, where the Italian system was lower. Table 3 gives an overview of the environmental impacts of the different milk production systems analyzed.

The higher use of concentrates in the foreign systems led to a higher demand in phosphorus and potassium resources and to considerable higher values for deforestation, which was caused by the higher use of soya in the feed ration. Additionally, the foreign systems had a higher water use, which was a direct consequence of the higher irrigation during the cultivation of the concentrates used. Only for land competition one foreign system (Italy) achieved lower values than the Swiss system. This was due to its concentrate based ration with a very low share of grass, which leads to a high energy yield per hectare land occupied. For all other environmental impacts, the higher milk yield through increased use of concentrates in the foreign systems did not result in lower environmental impacts. On the contrary, the energy required to produce one kilogram of milk increased with the milk yield per cow due to the purchase of extra feed and the use of energy carriers on the farm, both of which were higher in foreign systems than in Switzerland (Figure 2). In addition, the higher restocking rates in the foreign systems lead to a higher impact of the purchased animals.

Regarding the global warming potential, the higher milk yields in the foreign systems led to lower methane emissions; however, for the total global warming potential there was no difference between the systems analyzed. The lower methane emissions in the foreign systems were compensated by higher CO_2-emissions caused by the higher energy demand (Figure 3). The same mechanism was found for ozone formation, where the lower methane emissions were compensated by higher nitrous oxide emissions.

Table 3. Overview of the environmental impacts per kg milk of milk production in Switzerland (Milk CH), Germany (Typ. Milk DE), France (Typ. Milk FR) and Italy (Typ. Milk IT). WSI: water stress index, N: nitrogen, P: phosphorus

Environmental impact	***Unit***	**Milk CH**	**Typ. Milk FR**	**Typ. Milk DE**	**Typ. Milk IT**
Non-renewable energy demand	*MJ-Eq.*	4.31E+00	4.64E+00	4.84E+00	6.41E+00
Global warming potential	*kg CO_2-Eq.*	1.26E+00	1.32E+00	1.31E+00	1.21E+00
Ozone formation potential (vegetation)	*m^2*ppm*h*	1.38E+01	1.36E+01	1.44E+01	1.33E+01
Ozone formation potential (human)	*Person*ppm*h*	1.08E-03	1.06E-03	1.12E-03	9.96E-04
demand for potassium resources	*kg*	9.63E-04	6.57E-03	2.63E-03	7.47E-03
Demand for phosphorus resources	*kg*	1.05E-03	1.97E-03	2.15E-03	1.44E-03
Land competition	*m^2a*	1.71E+00	1.57E+00	1.75E+00	1.42E+00
Deforestation	*m^2*	4.30E-04	7.28E-03	1.08E-02	1.77E-02
Water use (WSI)	*m^3*	9.00E-04	1.61E-03	2.47E-03	5.49E-03
Terrestrial Eutrophication potential	*m^2*	9.12E-01	1.10E+00	9.96E-01	8.27E-01
Aquatic eutrophication potential N	*kg N*	4.64E-03	6.57E-03	5.52E-03	4.37E-03
Aquatic eutrophication potential P	*kg P*	1.85E-04	3.60E-04	3.11E-04	3.28E-04
Acidification potential	*m^2*	2.24E-01	2.69E-01	2.46E-01	2.14E-01
Terrestrial ecotoxicity potential	*kg 1,4-DB-Eq.*	5.99E-04	1.20E-03	6.88E-04	7.61E-04
aquatic ecotoxicity potential	*kg 1,4-DB-Eq.*	9.08E-02	1.11E-01	7.87E-02	1.10E-01
Human toxicity potential	*kg 1,4-DB-Eq.*	2.12E-01	2.18E-01	2.12E-01	2.67E-01

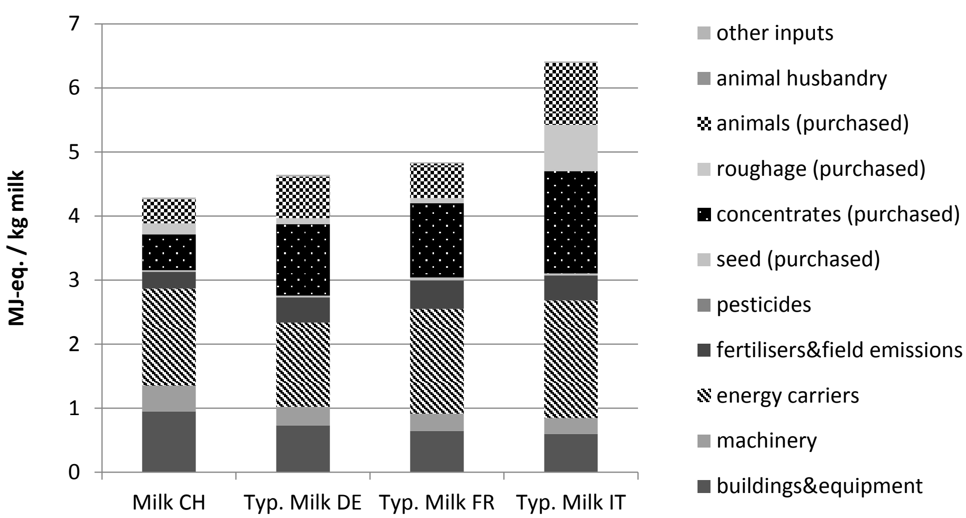

Figure 2. Energy demand of the different milk production systems analyzed.

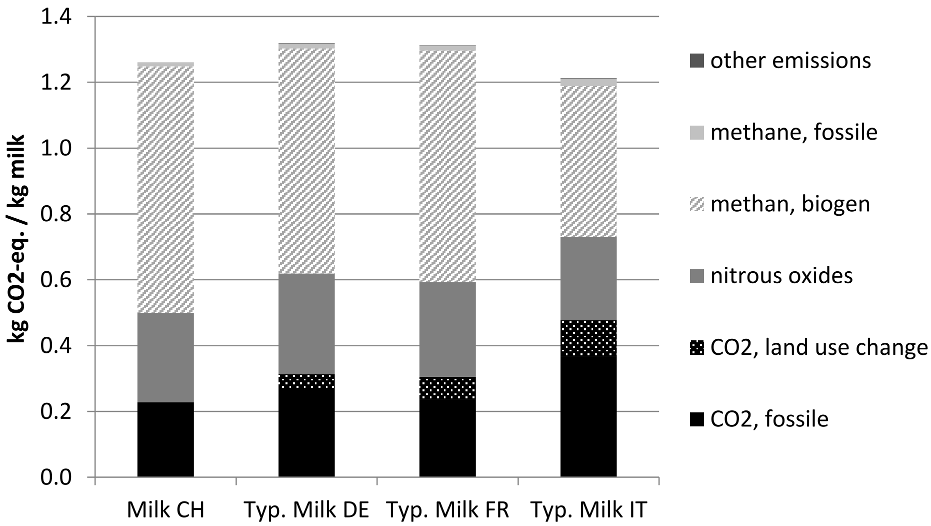

Figure 3. global warming potential of the different milk production systems analyzed

For the nutrient related impacts, the foreign systems had a higher aquatic eutrophication potential from phosphorus compounds. This was mainly due to higher field emissions during cultivation of the feedstuff used. The German system was also higher for the other nutrient related impacts (terrestrial eutrophication potential, aquatic eutrophication potential phosphorus and acidification potential). In Germany, the fertilization level on the agricultural area used was highest; in particular there was the highest amount of slurry applied per hectare, which lead to high emissions of ammonia.

For the toxicity related impacts, there were no relevant differences between the systems analyzed. This was also due to the high uncertainties in this field, so that relatively big differences are still not considered as being relevant. Only for the terrestrial ecotoxicity potential the German system had higher impacts than the Swiss system.

Comparing dairy systems within Switzerland showed that mountain production had generally higher impacts than lowland production due to less favorable conditions like lower yields, longer winter feeding periods and steep slopes in the mountains. Grassland based dairy systems with moderate milk yield had lower ecotoxicity impacts, lower use of mineral resources (P and K) and lower contribution to deforestation than the standard dairy system, but similar or higher impacts regarding the other categories.

3.2. Results at point of sale

The environmental impacts per kilogram of cheese followed the same pattern as the environmental impacts per kilogram of milk, since the agricultural phase dominated the environmental impact of cheese production up to the point of sale. The downstream process with the strongest influence was the cheese dairy, followed by the transports. The impact of the distribution center was negligible.

4. Discussion

The good growing conditions for grassland with abundant precipitation and a high quality of roughage in Switzerland allow to produce milk at moderate intensity levels with small amounts of concentrates in an efficient way. A higher use of concentrates with the resulting higher milk yield in the foreign systems did not lead to an improvement of the environmental performance of those systems. On the other hand, the analyses of modeled milk production systems with different share of grass in the feed ration within Switzerland showed a lower performance for the systems with a high share of grass in the diet.

This shows that when comparing different feeding strategies, not only the directly affected parameters such as feed intake and type of feed should be considered, but all relevant production parameters as well as site conditions must be included. The impact of a feeding strategy on health parameters and service life of dairy cows are particularly important. The foreign systems consistently exhibited a lower service life and a higher replacement rate than the Swiss systems, which significantly contributed to the higher energy requirement.

For the methane related impacts, this study revealed no difference between the Swiss and the foreign systems. However, methane emissions strongly depend on the equations used to calculate the emissions from enteric fermentation, as shown by Hagemann et al. (2011). According to the method of the Intergovernmental Panel on Climate Change (Eggleston et al. 2006) used in this study the methane emissions increase proportionally to the gross energy intake of dairy cows. The statistical analysis of a large number of published experimental data carried out by Ramin & Huhtanen (2013) confirms that gross energy intake is the main driving factor of methane emissions. However, the quality of the estimate could be improved by including several characteristics of the feed ration. Further studies are needed to estimate the methane emissions of grass based systems compared to concentrate based systems.

Two other essential parameters for the environmental effects of milk production are the manure management and manure spreading. While a high proportion of manure in the total fertilization has a positive impact on energy demand as well as on resource use phosphorus and potassium, there is a negative influence on the nutrient-related environmental impacts due to the slurry-related ammonia emissions. The modeling of the individual milk production systems revealed to be particularly difficult in this regard, as for the individual countries only few data on manure spreading on crop level was available and there was a complete lack of information about application dates. The management of the on-farm agricultural area for the production of roughage in the foreign systems is therefore partially modeled with Swiss data. Including country specific data on manure management and manure spreading could change the results in particular for the nutrient related impacts.

Another difficulty is the high variability in the milk production systems within a country. The Swiss results showed that the environmental impacts of different milk producing systems within a country can vary significantly. Guerci et al. (2013) compared twelve different milk producing farms in Denmark, Germany and Italy and analyzed their energy demand, global warming-, acidification- and eutrophication potential per kilogram of milk produced. He stated a significant positive effect of a high proportion of grassland on energy use, global warming potential and acidification. However, as only 12 farms were assessed, a more general analysis of the relation between the production and the environmental impact has to be handled with care, especially as the study revealed huge variability in environmental impact within the group of farms analyzed (Guerci et al. 2013).

To compare the milk production of a country with the one of another country, all milk production systems existing in a country would need to be modeled to form the respective national average. The milk producing systems in this study refer to a typical system and – except in the Swiss case – not to the average milk production of the country concerned. This must be considered when interpreting the results. Nevertheless, this study shows which parameters are important for the environmental impact of milk production and provides important information on existing differences between the countries studied.

5. Conclusion

The environmental impacts of cheese production are dominated by milk production. The study showed that there is no simple relationship between amount of concentrates, milk yield and environmental impacts; instead the results depend on the whole production system. Site conditions can influence the environmental impacts significantly: In Switzerland, the good growing conditions for grassland with abundant precipitation and a high quality of roughage allow to produce milk at moderate intensity level with small amounts of concentrates in an efficient way.

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