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Dalla Riva, A., Burek, J., Kim, D., Thoma, G., Cassandro, M., De Marchi, M.

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Poljoprivredni fakultet u Osijeku, Poljoprivredni institut Osijek

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THE ENVIRONMENTAL IMPACT OF COW MILK IN THE NORTHEAST OF ITALY

***Dalla Riva, A.*[(1)]*, Burek, J.* [(2)]*, Kim, D.*[(2)]*, Thoma, G.*[(2)]*, Cassandro, M.*[(1)]*, De Marchi, M.* [(1)]**

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SUMMARY

This study presents a "from cradle to farm gate" Life Cycle Assessment on cow milk produced in Northeast Italy. System boundaries consider milk and meat delivered at farm gate, including all upstream emissions. All farm activities were considered. Inputs and outputs required in one year are counted and information about 34 dairy farms are used to represent the production area. Different allocation approaches were used to share resources and emissions between milk and meat. Functional unit was one kg of raw milk. The Ecoinvent v3.1 and Agri-footprint v1.0 database were used for secondary data, and SimaPro© 8 was the main software in the analysis. The following impact categories were investigated: Climate Change (CC), Terrestrial Acidification (TA), Freshwater Eutrophication (FE), Land Occupation (LO), Water Depletion (WD) and Cumulative Fossil Energy Demand (CFED). Purchased feed production was the first emitter, followed by on-farm crop production, animals and manure management emissions. Considering the most debated impact categories, 1.80-2.19 kg CO_2***eq and 8.84-10.78 MJ represent, respectively, CC and CFED per kg of raw milk. This research could be applied in regional studies on environmental impact of Italian dairy production.***

Key-words: LCA, dairy farm, milk, environmental impact

INTRODUCTION

Life Cycle Assessment is becoming a solid tool to identify and estimate main emission drivers in dairy production chain. Italy has a developed dairy industry, mainly based on traditional cheeses and PDO products (Cassandro, 2003). Considering the several kinds of Italian dairy products and the difference dairy farming systems existing in the Italian territory, an estimation of environmental impacts occurring in raw milk production at farm is advantageous in order to better represents each production areas, furthermore considering that in terms of overall environmental impacts, the majority emission drivers in dairy products are located to raw milk production at farm (Kim et al., 2013). Several environmental impacts such as Climate Change, Acidification, Eutrophication, Land Use, non-renewable energy use, and other impacts belong to dairy farms as shown by Italian (Guerci et al., 2013a,b) and international (Thoma et al., 2013) researchers. The aim of this study was to estimate environmental impact of one kg of raw milk production in the Northeast Italy.

MATERIAL AND METHODS

Life Cycle Assessment (LCA), ISO 14040-14044 (ISO 2006), was used to perform the study, adopting a *"from cradle to farm gate"* perspective and an attributional approach (Thoma et al., 2013).

The functional unit used in this study was 1 kg of raw milk delivered at farm gate. Meanwhile 1 kg of Live Weight delivered at farm gate was the functional unit to express meat production. Six allocation methods were considered to allocate inputs and final emissions to milk and meat: *biological* (IDF, 2010), *economic* (using annual economic revenue derived from product sales), *mass*, *fat* and *protein content* of delivered products; moreover a *No-Allocation* approach is performed attributing all emissions to milk.

(1) Ph.D. Alessandro Dalla Riva (alessandro.dallariva.1@studenti.unipd.it), Prof. Dr. Martino Cassandro, Assoc. Prof. Massimo De Marchi - University of Padova, Department of Agronomy, Food, Natural resources, Animals and Environment, Viale dell'Università 16, 35020 Legnaro (PD), Italy. (2) Research Assoc. Jasmina Burek, Postdoctoral Fellow Daesoo Kim, Prof. Dr. Greg Thoma - University of Arkansas, Ralph E. Martin Department of Chemical Engineering, 3202 Bell Engineering Center, Fayetteville, AR 72701-1201, United States

System boundaries considered milk and meat delivered at farm gate, including all upstream emissions. All farm activities were considered. Main product was raw milk, but meat production was a relevant co-product in dairy farms. Meat derived from: culled cows, exceed heifers, male calves, male and female animals breed as beef, and reproduction bulls. Manure produced was spread in the on-farm land and it was not considered as co-products, and emissions from manure were part of the system.

Thirty-four dairy farms (75% of annual milk production) were selected among the 65 dairy farms that conferred milk to the dairy cooperative. Milk produced by members was collected and processed by a unique dairy plant in order to produce Italian PDO (Protected Designation of Origin) cheeses. Annual presence of animals in farm and feed rations were investigated in all 65 dairy farms. During 2014, data were collected throughout personal interviews with farm owners, covering all farm processes during 2013. The study pursues the idea to obtain the best realistic representation of dairy area emissions, then all data collected were considered valid data, and only limited adaptations and supplements were applied, where lack of data were presented.

All resources incoming in the whole dairy area during one year were counted and used to assess environmental impact, except emissions related to building, machinery, medicines and refrigerant gases due to lack of data or due to their low importance on the total impact (Thomassen et al., 2008). Data collected regard: land, water, electricity, fuels (diesel and LPG), plastic (PP, HDPE, LLDPE) and paper (cardboard, kraft paper and tissue paper) packaging and related waste, fertilizers, chemicals, pesticides, bedding materials, purchased feeds, crops produced on farm. Raw material compositions and active ingredients, and their related emissions, were considered for fertilizers, chemicals, pesticides, bedding materials, purchased feeds. Transport to farm and from farm was associated to all resources. Emissions on-farm and off-farm were estimated using different methods: Ellis et al. (2007) for enteric CH_4; IPCC (2006), with updated conversion factors (IPCC, 2013), is used for CH_4 and N_2O emissions from manure management, and NO_3 leaching and run-off at field level; Mikkelsen et al. (2006) for CH_4 from bedding materials; EEA (2013) for NH_3, NO_X, NMVOC, PM_{10}, $PM_{2.5}$, NO and pesticides emissions from on-farm crop production at field level; Nemecek et al. (2007) for PO_4^{3-} leaching and run-off at field level; UFE/UFAM (2014) for diesel and LPG burning emissions. The Ecoinvent v3.1 and Agri-Footprint v1.0 database were used for secondary data; where possible databases were implemented with local data to increase the precision on the results, such as local-real transport for all resources, except for fertilizers, chemicals and pesticides. Specific Italian recycling unit processes were adopted for paper waste (Arena et al., 2004) and plastic waste (Ferrari et al., 2005; Perugini et al., 2005).

SimaPro© 8 was used as the main software in the analysis (PRé Consultants, The Netherlands 2014).

Environmental impact estimation includes the following impact categories: Climate Change (CC), Terrestrial Acidification (TA), Freshwater Eutrophication (FE), Land Occupation (LO) and Water Depletion (WD) according ReCiPe Midpoint (H) v1.11 (Goedkoop M.Jet al., 2009), and Cumulative Fossil Energy Demand (CFED) according to Frischknecht et al. (2007) v1.09, excluding infrastructure processes and long-term emissions. Only classification and characterization LCA steps (ISO 14040-14044, 2006) are considered in the study.

RESULTS AND DISCUSSION

Results per kg of raw milk delivered at farm gate, throughout impact categories and allocations, are shown in Table 1. Considering impact drivers, purchased feed production was the main contributor on overall impact categories and allocations. Among allocation methods, the biological approach (IDF, 2010) is taken into account to explain the results: purchased feed production was the main emission driver in FE (83%), CFED (71%), LO (63%), AC (62%) and CC (53%), while on-farm crop production was the first contributor in WD (94%) and the second emitter in all impact categories, except in CC where animal emissions counted for 37% of the total CC. Contemplating CC category, CO_2, CH_4 and N_2O emissions represented, respectively, 55%, 38% and 7% of total CC impact: enteric CH_4 and manure management CH_4 are, respectively, 80% and 20% of CH_4 derived from animals. The highest CO_2 contribution of decreases when CO_2 from land transformation (51% of total CO_2) is not counted: CH_4 becomes the first contributor with 49% of total emissions (97% from animals), CO_2 marks 43% (mainly from fuel combustion), and N_2O grows to 9% (55% from on-farm crop production). In AC, NH_3 composed 84% of the total emissions; meanwhile organic and synthetic fertilizers used in purchased feed production counted 78% of emissions in FE.

Table 1. Emissions per kg of raw milk delivered at farm gate and allocation factor to milk using different allocation methods

Impact category	Biological	Economic	Mass	Fat	Protein	No-Allocation
Climate Change, kg CO_2 eq	1.80	2.06	2.13	1.80	1.84	2.19
Terrestrial Acidification, g SO_2 eq	13.20	15.13	15.61	13.20	13.52	16.10
Freshwater Eutrophication, g P eq	0.16	0.18	0.19	0.16	0.16	0.19
Land Occupation*, m^2a	1.64	1.89	1.95	1.64	1.68	2.01
Water Depletion, m^3	0.47	0.54	0.56	0.47	0.49	0.58
Cumulative Fossil Energy Demand, MJ	8.84	10.14	10.46	8.84	9.06	10.78
Allocation to milk, %	82	94	97	82	84	100

*: Agricultural + Urban + Natural transformation

Considering allocation approach to milk, our results were similar to those reported in the international methodology (IDF, 2010), while economic allocation values were similar to the results reported by Guerci et al. (2013a). Several *"from cradle to farm gate"* LCA have been performed for raw milk; these studies show results per kg of functional unit slightly lower than values estimated in the present study. Considering CC, an average value is 1.3 kg CO_2eq/kg milk (De Vrier and De Boer, 2010), although Guerci et al. (2013b) estimated values of 1.91 kg CO_2eq/kg ECM in Northern Italian dairy farms. Nevertheless, coherence is individualized in the main emission drivers. Italian authors (Fantin et al., 2011; Guerci et al., 2013a, 2013b) found on-farm emissions (mainly enteric, manure management and on-farm crop emissions) as the first emitter in CC, AC and FE, while purchased feed production as the second contributor in overall impacts and the first in CFED; moreover they underlined as enteric CH_4 was first contributor in CC, followed by CO_2 emissions. However, deep comparisons among studies are difficult due to different impacts under analysis, methods, functional units, system boundaries and emissions factors, such as the changing from IPCC (2006) to IPCC (2013). Reduction of impacts can achieve throughout rations for reducing enteric emissions, energy recovery technologies (such as manure anaerobic digestion), and the optimization in use as well as application of fertilizers.

CONCLUSION

In this assessment, purchased feed production deriving from the secondary data leads potential environmental impacts. This result derives by the choice to consider, and to break up, all concentrate feed used for each animal classes into singular raw materials. However, overlooking purchased feed impacts and CO_2 from land transformation, a general trend found in literature is recognized. An estimation of local emissions in raw milk production is better way to represent a specific dairy production. Comparison with other studies is made possible using international estimation methods for LCA and emissions. However, the specificity of region and data collected involves minor deep comparison with studies on national and international level.

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