FP7 SMEthane		

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Report on an initial life cycle assessment of a milk production system

Foreword

This work was carried out at the French National Institute for Agricultural research (INRA), France, as part of SMEthane work package 5 in view of assessing the environmental impact of different plant extracts on ruminant production systems at the farm scale level. A life cycle assessment (LCA) approach was applied on a modeled dairy production system. To perform a LCA, supplementary information on the production and distribution of additives was asked to companies. The application of the LCA approach is relatively new in this sector and the required information was not readily available to all partners. Nevertheless, two partners were able to supply these data on two products. The specific names of products have deliberately been omitted from this report. The general information provided in this report should be useful to all partners.

Executive Summary

The reduction of enteric CH4 in ruminant production represents both an environmental and a nutritional interest. Feed additives that were developed to improve animal performances and to reduce the production of CH4 were tested. Through the SMEthane project, we had access to enteric CH4 emission measurement from in vivo experiments and to information on the industrial production processes of two plant additives (additive 1 and 2). The objective of this work was to give a more holistic vision of the results obtained on animals in SMEthane trials by assessing other environmental impacts at the farm scale. Eight virtual farms with the same usable agricultural area (55 ha) and the same total milk production (250 000 liters of fat-and-protein-corrected milk) were simulated. Two reference systems, one with 11 % of silage maize in the forage area (FA, T10 %) and one with 33 % of silage maize in the FA (T30 %) were based on the work of Nguyen (2012). For additive 1 that was given to cull cows, we created four sub-systems, two within each reference system in which the additive in one case decreased CH4 /kg DMI by 20.4% and in the second case it decreased CH4 to the same degree and increased feed intake by 15 %. For additive 2 that was given to producing and dairy cows, the simulation was made on the two reference systems. The additive 2 increased by 4.8 % CH4 emissions by kg DMI. For both additives CH4 emission and intake data was based on SMEthane trials. The environmental impacts (climate change, eutrophication, total cumulative energy demand, acidification and land occupation) of the studied systems were calculated by the life cycle assessment (LCA) method. The results showed that climate change impact as well as other environmental impacts of the systems supplemented with additives decreased less than 1% as compared to the reference systems. The effect of additive 1 on the environmental impacts of the farm was very low. This can be explained by the fact that additive 1 was only given to cull cows which represented 1/3 of the herd and only during 2 months of fattening. Additive 2 increased climate change impact by up to 2.5% and other environmental impacts were also negatively affected. The effect of additive 2 on the environmental impacts of the T10% system was lower than those of the T30%. The contribution of additive 2 to energy demand was high (7.9 and 11.9%). In contrast and except for the energy demand of additive 2, additives intrinsically contributed to less than 0.1% for most environmental impacts studied. This means that if additives are effective at reducing enteric methane and if they are given to the majority of animals they could reduce the environmental impact of the farm. In this work, however, as the additives tested were only marginally effective in reducing enteric methane emissions their supplementation did not significantly modify the environmental impacts at the farm scale.

Key words: dairy system, enteric methane, environmental impacts, life cycle assessment

1. Introduction

Methane production from ruminants can account for a loss of between 2 and 12% of their daily ingested gross energy. This loss firstly is economically important to the producer and secondly has a negative environmental effect. The reduction of CH4 represents thus not only an environmental interest for the planet, but also a nutritional interest for the animal. Methane has a global warming potential 25 times that of carbon dioxide which makes it a very important gas in terms of Greenhouse Gas inventories produced by each country. There is a large variation in ruminant production systems across Europe due to differences in local climate and the type and availability of feeds given to animals. We used a virtual dairy cow farm (Nguyen et al. 2012) to simulate the different processes taking place in the farm. We made the inventory of all the resources needed and the emissions during the cycle of the dairy production system, from “cradle to the farm gate”. Hence, we made the inventory of all processes concerning: seed production, forage and crop cultivation, farm operations (animal production, electricity, etc.), sales of animal and forage at the farm gate and, finally, all the transports involved. In addition, we included the processes for plant additive extraction, production and distribution. We did not take into account all downstream operations (slaughtering, milk or meat transformation).
The effects of a plant extract might be beneficial in terms of reducing methane production at the animal scale but this might be at the cost of other environmental impacts (GHG, eutrophication) which in turn could be detrimental at the farm scale. The aim of this initial LCA was to assess global GHG environmental impacts (CH_4, CO_2 and N_2O) as well as other environmental impacts such as eutrophication and acidification induced by the use of plant extracts in a dairy farm from “cradle to the farm gate”. The second objective of this work was to give a larger scope of the results obtained at the animal scale in the context of the farm level, in order to evaluate the consistency of “animal targeted” methane abatement strategies.

2.0 Materials and Method

2.1 Life cycle analysis

- <u>System boundary and delimitations</u>

This is a cradle-to-farm-gate attributional Life Cycle Assessment study for a one-year period (figure 1). The studied system includes the production and delivery of resources produced both on-farm and off-farm. The inventory of the resources includes forage and crops produced on-farm on some parts of the usable agricultural area, whereas the animal feed supplements, the additives and the straw for the bedding were produced off-farm. The inventory also includes herd management and associated upstream processes, emissions from animals, and manure storage and application to grassland and cropland (figure 2). The transport of wheat grain, rapeseed and wheat straw leaving the system and the transport and slaughter of animals leaving the system are not included. Buildings are included, but veterinary medicines are not included due to lack of data.

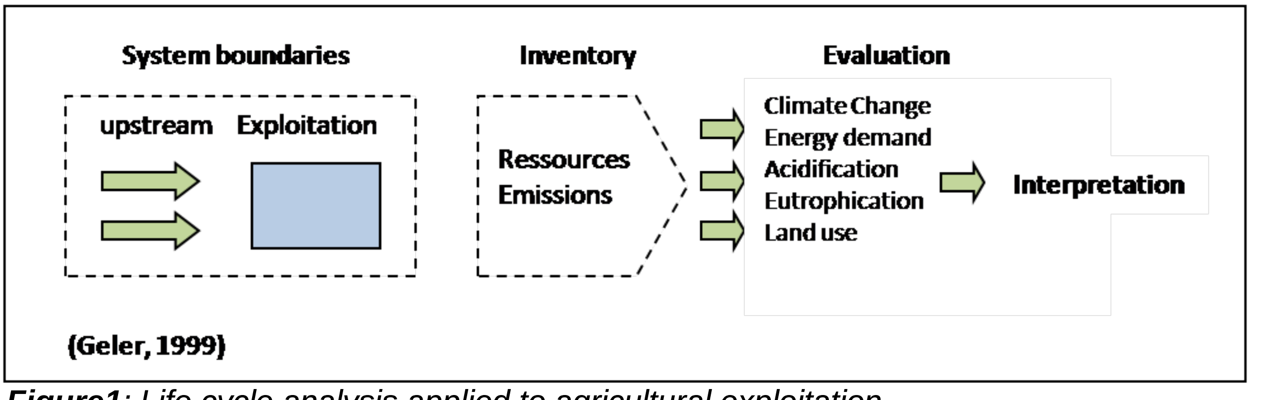


***Figure1**: Life cycle analysis applied to agricultural exploitation*

Eight virtual farms (i.e. a dairy sub-system plus an optional cash-crop system) with the same usable agricultural area (55 ha) and the same total milk production (250 000 litres of fat-and-protein-corrected milk, FPCM) were created (figure 3). Two reference systems, one with 11 % of silage maize in the forage area (FA, T10 %) and one with 33 % of silage maize in the FA (T30 %), based on the work of Nguyen (2012) (Table 1). Based on the two reference systems, we created four systems were additive 1 was added only to cull cows diets at a dose of 9 g/d/cow during a 2 months fattening and two systems were additive 2 extract was added to lactating dairy cows and cull cows diets at a dose of 54 g/d/cow during winter (when fed indoors). The UAA not used for forage was available for cash crops (i.e. wheat and rapeseed). Wheat was introduced to supply straw for bedding, and rapeseed was used to complete the rotation with grassland. These dairy sub-systems were characterised by the proportion of maize silage in the total forage area (three levels: 10 or 30%), cow breed (Holstein) and whether or not culled cow rations were supplemented with additives during a 2 months period.

- <u>Functional unit and co-product handling</u>

The impacts of the dairy sub-system (i.e. whole farm minus cash crops) were attributed to animal products per 1 kg of FPCM and per 1 kg of LW of finished cull cow, weaning calf and pregnant heifer at the farm exit gate. Economic allocation was used for animal products (i.e. commercialised milk, cull cows before finishing and weaned calves not used for replacement) produced by the dairy sub-system (dairy cows and replacement heifers) and for crop products and feed ingredients resulting from processes yielding several co-products (e.g. wheat grain

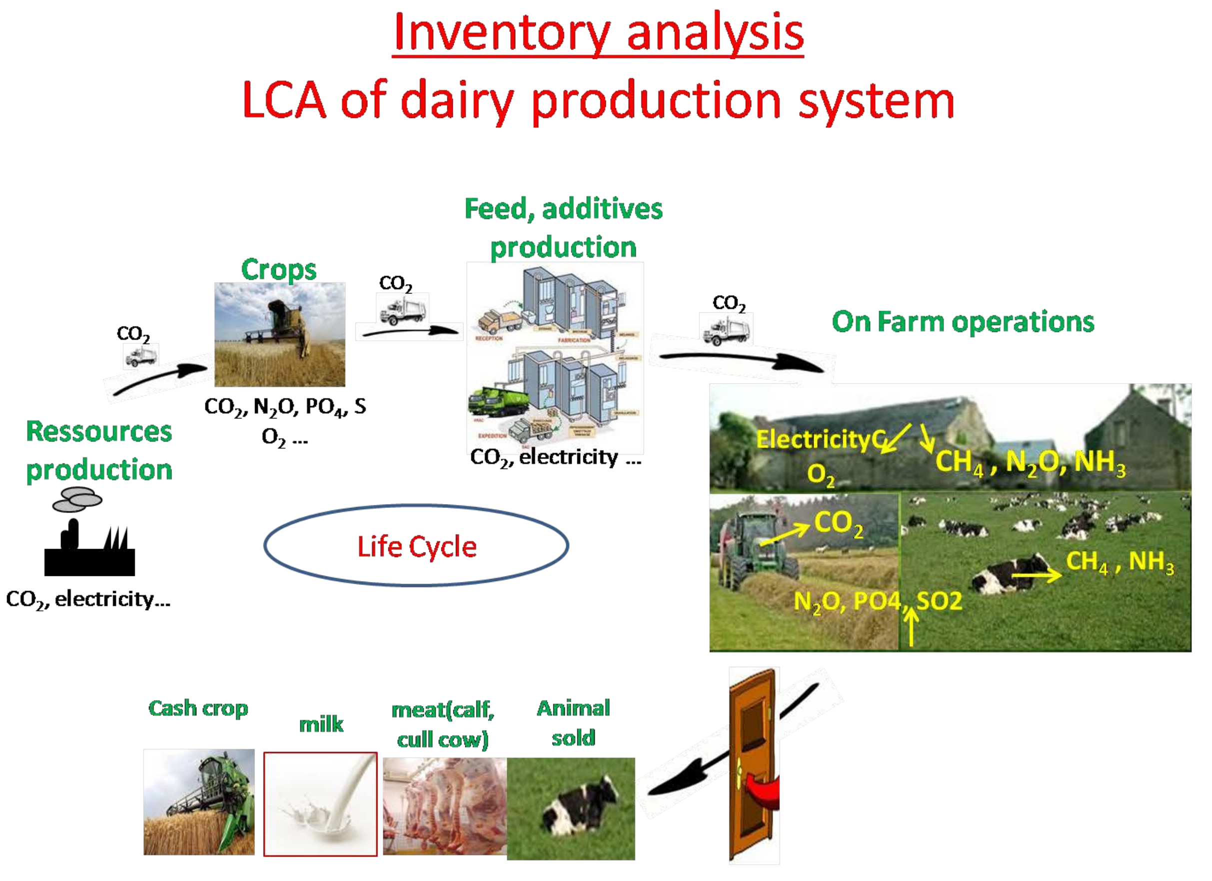


***Figure 2**: LCA of a dairy production system; Inventory analysis*

vs. straw).

- <u>Emissions estimates</u>

a) Methane

Enteric CH4 emissions were estimated for each class of cattle according to Vermorel et al. (2008) using animals' net-energy requirements, converted into metabolisable energy intake (MEI) and conversion factors from MEI to CH4 energy.

To represent the effect of diets supplemented with additives on CH4 emission, the variations (increase or decrease) of CH4 production (g CH4/kg DM intake) observed and based on the results obtained from experimental trials (WP4, D4.4) were used. Based on the two reference systems, we created four systems were additive 1 was added only to cull cows diets. In the first case, this supplementation decreased CH4 /kg DMI by 20.4% and in the second case, it decreased by 20.4 % CH4 / kg DMI and increased by 15 % DMI, based on the results obtained from experimental trials (WP4, D4.4). We also created two other systems where additive 2 was distributed to cull cows and dairy lactating cows diets, this resulted in an increase by 4.8 % of CH4 /kg DMI, based on the results obtained from experimental trials (WP4, D4.4). Emissions from slurry and solid manure produced by cattle, from application of slurry and solid manure on cropland were estimated according to IPCC (2006) Tier 2 (for CH4), based on Nguyen et al. (2012).

***Table 1**: Amount of additives used in the farms*

	Additive 1		Additive 2			
System	**T10% + Additive 1**	**T30% + Additive 1**	**T10% + Additive 2**		**T30% + Additive 2**	
Animal	Cull cow	Cull cow	Cull cow	Lactating cow	Cull cow	Lactating cow
Dose (g/d/animal)	9	9	54	54	54	54
Treatment application (d)	60	60	60	145	60	260
kg/year/animal	0.54	0.54	3.20	7.83	3.24	14.04
animals (head)	13	10	13	34	10	32
Total amount/ animal group (kg)	7.0	5.4	42.1	266.2	32.4	449.3
Farm total (kg)	7.02	5.40	308.34		481.70	

b) Nitrogen

Nitrogen excretion was calculated as the difference between an animal's total N intake in feed and the N retained for milk production and growth (meat production). Emissions from slurry and solid manure produced by the herd and from manure application on cropland and grassland were estimated according to IPCC (2006) Tier 2 (for N2O) and CORPEN (2006) (for NH3). Nitrate leaching was also estimated (Vertès et al. 2007, 2012) , P excreted on pasture (CORPEN, 1999) and P emissions (leaching, run-off and erosion) were estimated according to Nemecek and Kägi (2007).

c) Carbon dioxide

Carbon dioxide from transport during farm operation and feed processing were estimated and Carbon (C) sequestration for permanent grassland (i.e. older than 30 years) was estimated at 0.7 t CO2/ha/yr (Arrouays et al., 2002). It was assumed that temporary grassland sequestered about 1.8 t CO2/ha/yr. So, C sequestration for the entire grassland and cropland rotation (5 years of grass, 2 years of annual crops) was estimated at 1.8 t CO2/ha.

- <u>Life cycle impact evaluation</u>

The impact categories considered were climate change (CC), climate change including the effects of land use and land use change and C sequestration (CC/LULUC) (kg CO2 equivalent (eq.)), cumulative energy demand (CED) (MJ), eutrophication (EP) (g PO43- eq.), acidification (AC) (g SO2 eq.) and land occupation (LO) (m2*yr). The indicator value for each impact category was determined by multiplying the aggregated resources used and the aggregated emissions of each individual substance with a characterisation factor for each impact category to which it may potentially contribute. The CC impact excludes C sequestration in grassland and C emissions due to conversion of Brazilian forest to cropland, whereas the CC/LULUC impact includes them.

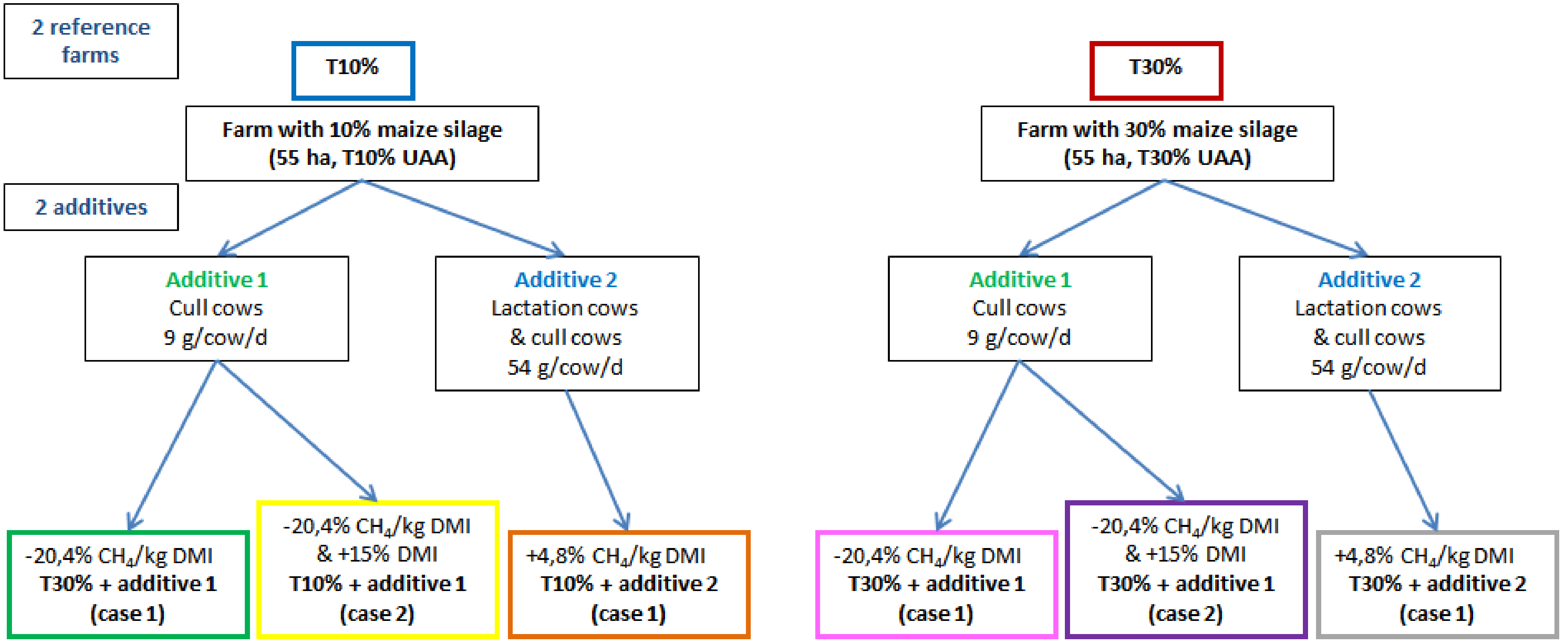


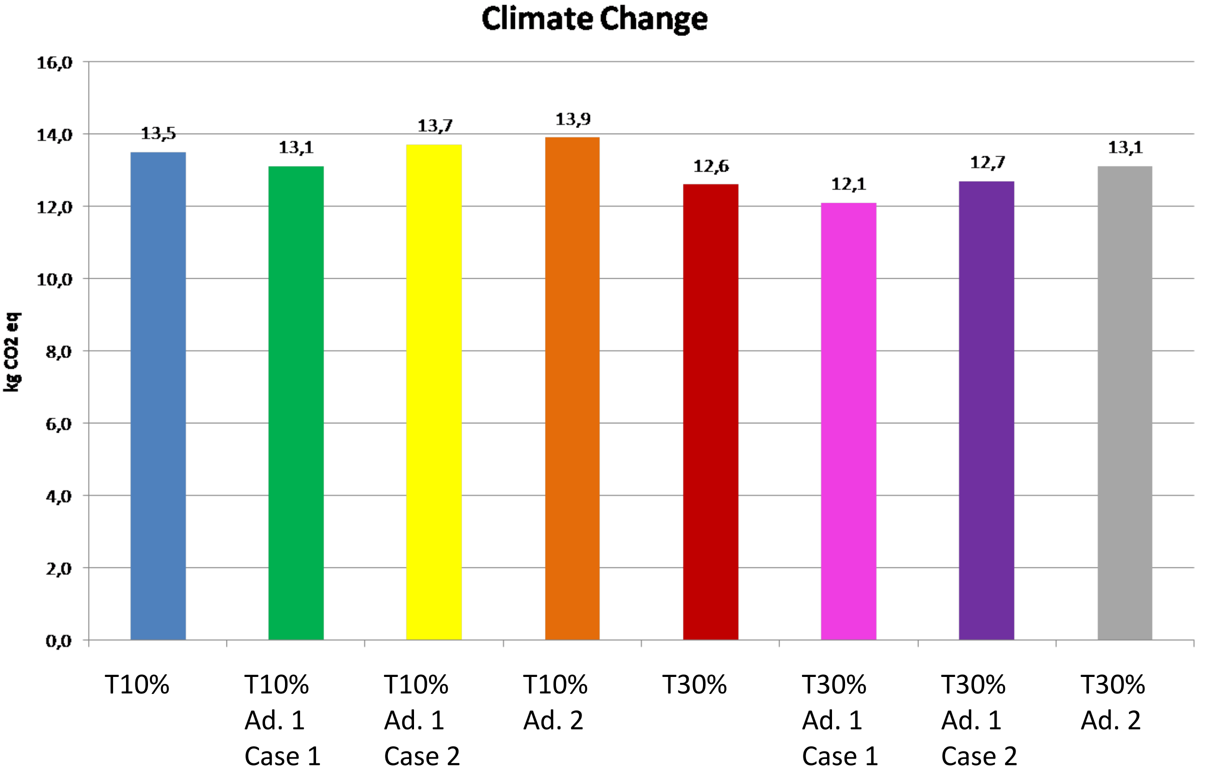
Figure 3: Virtual dairy farms simulated in the life cycle assessment.
Additive 1 in case 1 affected methane emissions and in case 2 affected methane emissions and intake.

2.1 Animal trial: methane emission measurements

Experimental data on the effectiveness and persistence of plant extracts in inhibiting methane production in dairy cow and sheep were described in WP 4 deliverable D4.4 and used to simulate the effect of additives fed to animals of the 8 virtual dairy farms.
The LCA was performed in dairy farms because it is the major market for ruminants' feed additives. However, some additives were not suitable for dairies because they can affect milk organoleptic properties (WP4 D4.3). That's why additive 1 was only fed to cull cows during a 2 months fattening period. For this type of additive, the LCA should be performed on beef production virtual farms.

3.0 Results

3.1 Environmental impacts of the additives at the farm scale for 1kg of carcass weight of cull cow for the 8 virtual farms



a) Climate Change
The production of 1 kg of carcass weight of cull cow emitted 13.5 and 12.6 kg CO2 eq for the T10% and T30% systems, respectively. Additive 1 supplementation decreased marginally CO2 eq emissions in case 1 when additive decreased enteric methane emissions on animals but when the decrease in emissions was accompanied with increases in feed intake (case 2) values did not differ from controls. As for additive 2, the supplementation marginally increased emissions as compared to corresponding controls.

b) Eutrophisation
The production of 1 kg of carcass weight of cull cow produced 0.042 and 0.040 kg PO43- eq for T10% and T30% system. Additive 1 supplementation lead to the production of 0.040 and 0.041 kg PO43- eq for T10% + Additive 1 case 1 and T10% + Additive 1 case 2, respectively. Additive 2 supplementation lead to emissions of 0.043 and 0.040 kg PO43- eq for T10% + additive 2 case 1 and T30% + additive 2 case 1, respectively.

The other impacts are presented in table 2.

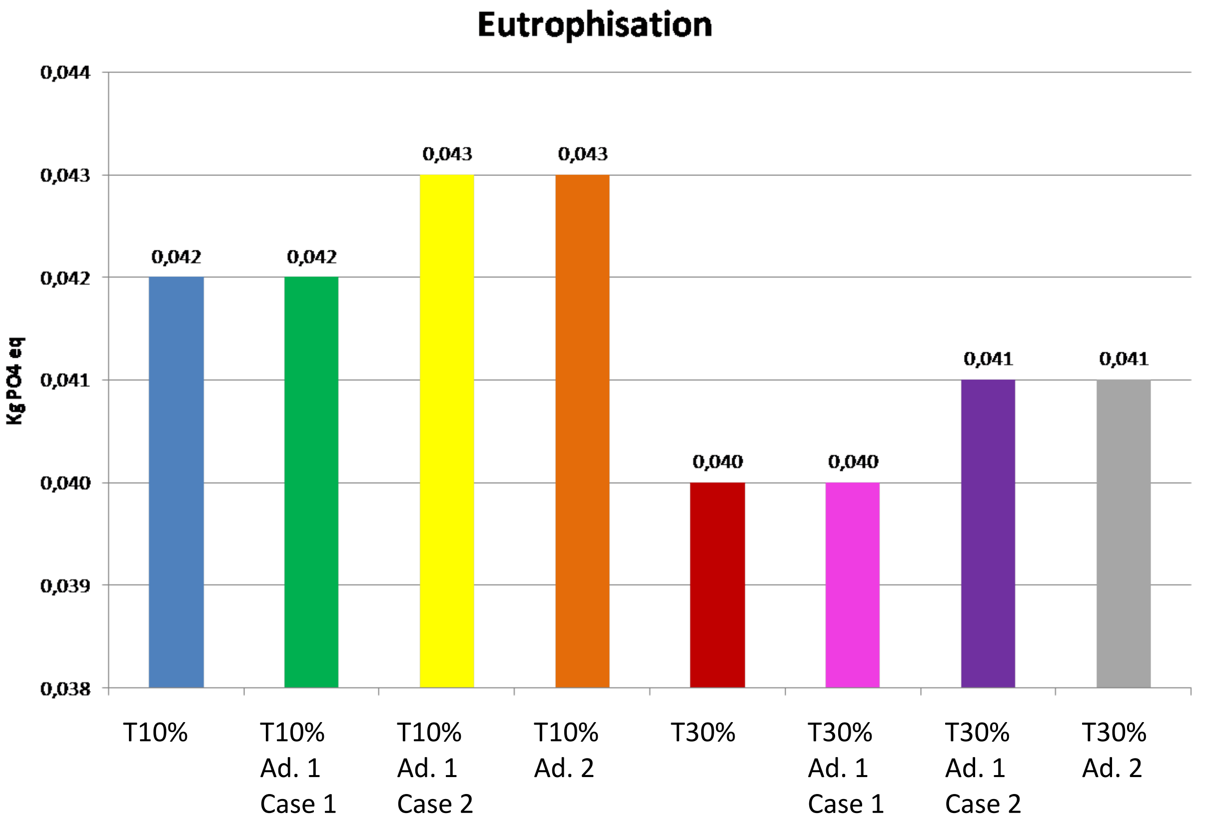
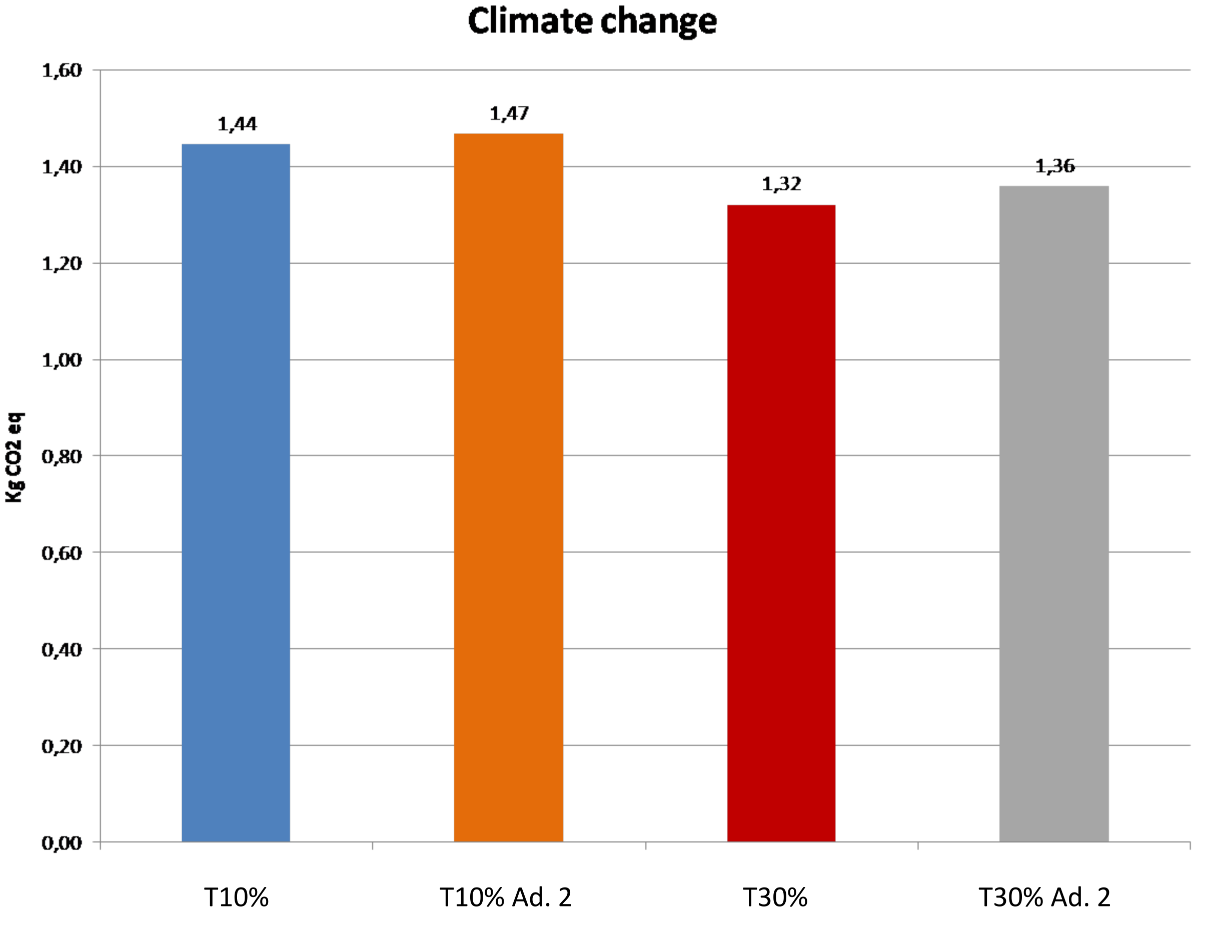


***Table 2**: Other Environmental impacts of the additives for the different virtual dairy farms*

Category	Energy demand (MJ)	Acidification (kg SO_2 eq)	Land use (m^2*a)
T10%	41	0.093	13.6
T10% + Additive 1 case 1	41	0.093	13.6
T10% + Additive 1 case 2	43	0.097	14.2
T10% + additive 2 case 1	48	0.095	13.8
T30%	38	0.089	11.6
T30% + Additive 1 case 1	39	0.090	11.7
T30% + Additive 1 case 2	41	0.093	12.3
T30% + additive 2 case 1	48	0.092	12.0

3.2 Environmental impacts of additive 2 at the farm scale for 1 kg of fat and protein corrected milk for the 4 virtual farms

a) Climate Change



One kg of fat and protein corrected milk produced 1.44 and 1.32 kg CO2 eq for T10% and T30% system, respectively. Additive 2 supplementation lead to the emission of 1.47 and 1.36 kg CO2 eq for T10% + additive 2 case 1 and T30% + additive 2 case 1, respectively.

b) Other impacts

Impacts	**Eutrophisation (kg PO_4^{3-} éq)**	**Energy demand (MJ)**	**Acidification (kg SO_2 éq)**	**Land use (m^2*a)**
T10%	0.005	4.41	0.011	1.48
T10% + additive 2	0.005	4.83	0.011	1.50
T30%	0.005	4.08	0.011	1.20
T30% + additive 2	0.005	4.81	0.011	1.22

One kg of fat and protein corrected milk produced 0.005 et 0.005 kg PO43- eq for eutrophisation, used 4.41 and 4.08 eq MJ for energy demand, produced 0.011 and 0.011 kg SO2 eq for acidification and 1.48 and 1.20 m2*a are needed for land use, for T10% and T30% system, respectively.

Additive 2 supplementation lead to 0.005 and 0.005 kg PO43- éq for eutrophisation, used 4.83 and 4.81 eq MJ for energy demand, produced 0.011 and 0.011 kg SO2 eq for acidification and 1.50 and 1.22 m2*a are needed for land use, for T10% + additive 2 case 1 and T30% + additive 2 case 1 system, respectively.

3.3 Contribution of the additives to the farm environmental impacts

Table 3*: Contribution of additive 1 to the farm environmental impacts*

Impacts	Unit	Virtual farms	Farm	Additive 1 use	Contribution of Additive 1 use (%)
Climate change	kg CO_2 eq	T10% + GE case 1	503 760	74	0.01
		T30% + GE case 1	474 590	57	0.01
Eutrophisation	kg PO_4^{3-}eq	T10% + GE case 1	2 147	0.4	0.02
		T30% + GE case 1	2 250	0.3	0.01
Energy demand	MJ	T10% + GE case 1	1 668 207	1 855	0.11
		T30% + GE case 1	1 656 771	1 427	0.09
Acidification	kg SO_2 eq	T10% + GE case 1	3 716	0.7	0.02
		T30% + GE case 1	3 608	0.5	0.01
Land use	m^2*a	T10% + GE case 1	644 142	134	0.02
		T30% + GE case 1	619 999	103	0.02

Additive 1 use produced 74 and 57 kg CO2 eq which represented a contribution of 0,01% and 0,01% to climate change 0,4 and 0,3 kg PO43-eq which represented a contribution of 0,02% and 0,01% for eutrophisation and 0,7 and 0,5 kg SO2 eq which represented a contribution of 0,02% et 0,01% for acidification, used 1 855 and 1 427 MJ which represented a contribution of 0,11% et 0,09% for energy demand 134 and 103 m2*a which represented a contribution of 0,02% et 0,02% for land use, for T10% + Additive 1 case 1 and T10% + Additive 1 case 2, respectively.

The results showed that the climate change as well as the other environmental impacts of the systems supplemented with the additives was slightly different (less than 1%) as compared to those of the reference systems. The effect of additive 1 on the environmental impacts was similar among the different reference systems. The contribution of additive 1 to the potential environmental impacts of the farm is very low. This can be explained by the fact that additive 1 was only supplemented to cull cows diets which represent 1/3 of the herd and only during 2 months of fattening. As compared with reference systems supplemented with additive 2 were higher (1.5 and 2.5%) for climate change, as well as for the other environmental impacts. The effect of additive 2 on the environmental impacts of the T10% system is lower than those of the T30%. The contribution of additive 2 to energy demand is high (7.9 and 11.9%). Globally, as compared with the reference systems, additives supplementation did not significantly modify environmental impacts at the farm scale.