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## Emission of greenhouse gas, developing management and animal farming systems to assist mitigation.

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### Introduction

Animal production may have adverse effects on many environmental aspects including air and water pollution, degradation of soil quality, reduction of biodiversity and global climate change. According to FAO (Steinfeld et al., 2006) about 12% of total emission of greenhouse gas is related to livestock production. This contribution is even higher (18%) when the deforestation related to the expansion of livestock production area is also considered. The emission of greenhouse gas in livestock production systems originates mainly from the animals (enteric fermentations), the manure, and the fields used for the production of feed and forages. This means that mitigation can be achieved in different ways related to animal feeding and management, manure collection, storage and spreading, and management of crops for feed production, and also by more drastic changes of the whole production system.

In this paper, we will first present the respective contributions of the different processes involved in the emission of greenhouse gas from conventional animal production systems. We will then try to evaluate the variability existing among production systems. Finally, the effects of different mitigation options will be considered.

### Contribution of the different production process to GHG emission in animal farming systems

The relative contributions of enteric fermentation, manure handling and production of forages and feed to total GHG emission in pig and dairy farm are given in table 1. These data were calculated by life cycle assessment (LCA). The emission for pig production is for a typical conventional pig farm with good agricultural practices in Brittany region (France). It was estimated from Basset-Mens and van der Werf (2005). The emission for dairy production corresponds to the average calculated from 46 farms also from Brittany. It was estimated from Roger et al (2007). In that calculation global warming potential is determined in kg CO<sub>2</sub>-equivalent, CO<sub>2</sub>:1, N<sub>2</sub>O:310, CH<sub>4</sub>:21 (IPCC, 2006). In LCA the functional units used to express emissions can be either the product or the land used for production. It is generally recommended to express the emission per unit of product in the case of global impacts, such as global warming, whereas the emission per ha of land has also to be considered for local impacts, such as eutrophication. The expression per ha of land may also be of interest when comparing different productions, such as pork and dairy production.

**Table 1.** Evaluation of greenhouse gas emissions (eq CO<sub>2</sub>) in swine and dairy production.

	pork production <sup>1</sup>		dairy production <sup>2</sup>	
	kg eq CO <sub>2</sub>	% of total	kg eq CO <sub>2</sub>	% of total
Per unit product (kg pig, L milk)	2.47	100	0.88	100
Origin				
Enteric fermentation	0.08	3.2	0.35	40.0
Manure handling	0.68	27.6	0.16	18.0
Production of forages and feed	1.67	67.6	0.32	36.0
Others	0.04	1.6	0.05	6.0
Total				
Type of gas				
CH <sub>4</sub>	0.49	19.9	0.46	52.8
N <sub>2</sub> O	1.03	41.8	0.26	29.2
CO <sub>2</sub>	0.95	38.3	0.16	17.9
Per ha of land per year	4240		5080	

<sup>1</sup>adapted from Basset-Mens and van der Werf (2005)

<sup>2</sup>adapted from Roger et al. (2007)

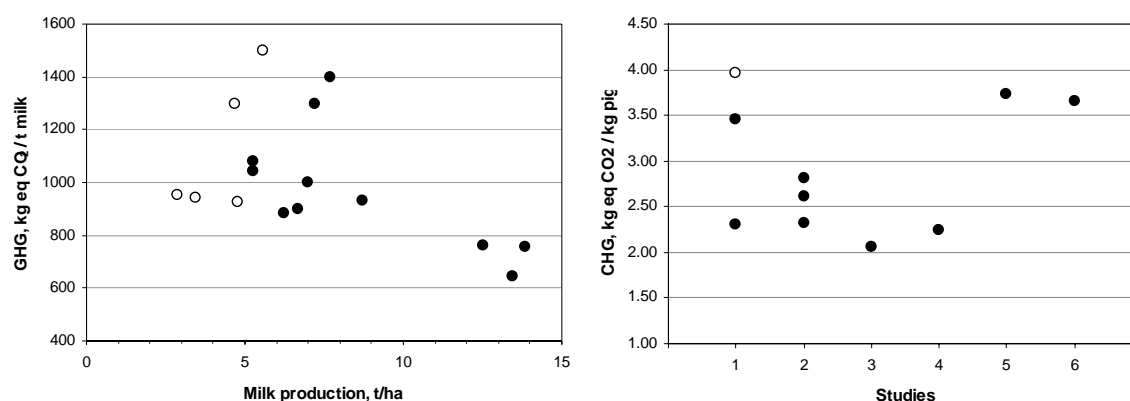
The results shown in table 1 indicate that the average GHG emission per ha of land is slightly higher for dairy than for pig production. However, the most significant difference between the two production systems relates to the origin of the GHG. In the case of ruminants most of the GHG production is related to enteric fermentation (40%), the second most relevant contribution being that related to the production of forages and feeds (36%). In the case of monogastric animals the production of feed is the major contributor (68%) followed by manure

handling (28%), with a very limited contribution of enteric fermentation. This results in major differences in the contribution of the different gases to total emission. Nitrous oxide and CO<sub>2</sub> are the major contributors for pork production systems whereas CH<sub>4</sub> contributes most in the case of dairy production.

The strategy for mitigation in a given system will depend on both the contribution of the different activities, including animal raising, manure handling and feed production, to total emission, and the possible improvement within each activity. A marginal improvement of a highly contributing activity might be as efficient as a more drastic improvement of a modest contributing activity. However this requires information about the variations of emissions between systems, for instance comparing conventional and organic farming, and between farms in a given system, in order to identify the possible improvements.

### Variability of GHG emission between livestock farming systems

Different estimations of GHG emissions from dairy and pig production systems found in the literature are reviewed in figure 1. In the case of milk production the values were plotted against the amount of milk produced per ha, giving an indication of intensity of land use. This was not possible for pig production systems because in most studies the information about land use was not available.



**Figure 1.** Estimation from literature studies of GHG emission in conventional (●) or organic (○) dairy (6 studies) and pig production (6 studies) systems. From Cederberg and Mattson (2000), Haas et al. (2001), Cederberg and Flysö (2004), Thomassen et al. (2008), Roger et al., 2007 and Basset-Mens et al. (2007) for dairy systems, and Basset-Mens and van de Werf (2005), Cederberg, (2002), Dalgaard and Halberg (2005), Blonk et al. (1997, cited by Basset-Mens and van de Werf, 2005 ), Carlsson-Kanyama (1998).

The estimations of GHG emission are highly variable among studies, between 600 and 1500 kg eq CO<sub>2</sub> per t milk, and between 2 and 4 kg eq CO<sub>2</sub> per kg pig. Part of this variability might be related to differences in methodology, but it can also be explained by differences in production systems between studies. In the case of pig production the highest values were found in alternative production systems. This was partly related to the raising of fattening pigs on straw bedding which increased the emission of N<sub>2</sub>O from manure and to the lower productivity of animals and land in these systems (Basset-Mens and van de Werf, 2005). In that study, organic pig farming resulted in a significantly higher emission of GHG per kg pig produced compared to conventional production. However when expressed per ha of land used GHG emission was similar for both systems. GHG emissions from organic and conventional dairy farms were compared in five studies (figure 1). The results indicate very similar emissions for both systems, with on average 1090 and 1120 kg eq CO<sub>2</sub> per t milk for the conventional and the organic production systems, respectively. However, because of a lower milk production per ha of land for organic farming, its GHG emission per ha was lower (4800 versus 7000 kg eq CO<sub>2</sub> per ha). According to the data presented in figure 1 there is no clear relationship between the emission of GHG per t milk and the intensity of milk production per ha. However, the studies having the highest milk production per ha present the lowest level of GHG emission per kg milk. For the intermediate range of milk production per ha there is a large variations in the level of emissions per t milk, suggesting possible improvements for all systems. In the same way, Basset-Mens and van der Werf (2005) estimated the variability of emissions of GHG in different pig production systems and suggested that variation within systems was as high as between systems.

Another important point to consider is the uncertainty of the estimation of GHG emissions which may also contribute to explain differences between studies. Indeed, the information relative to the emission in some systems is scarce and values are based on a very limited number of studies. For instance, the emission of N<sub>2</sub>O is generally not well known, although in some systems the contribution of this gas may be very high. Basset-Mens et al. (2006) evaluated the uncertainty of GHG emission in different pig production systems using a sensitivity analysis. According to their results uncertainty was large (> 50%) and originated mainly from the estimation of

field emissions of  $\text{N}_2\text{O}$  and, when the pigs were housed on litter bedding, of emissions of  $\text{N}_2\text{O}$  from manure. This highlights the necessity of improving our knowledge on the factors affecting the emissions of GHG.

### Mitigation strategies

The improvement of animal productivity was suggested by FAO (2006) as an efficient way to increase world production of animal products and meet the increasing world demand, without increasing the use of land or the emission of GHG. As indicated in table 1 most of the GHG emission is related to the production of feed and its digestion by animals. Moreover the amount of manure and consequently GHG emissions from manure are also related to the amount of feed used. The efficiency of conversion of feed to animal products depends on the relative contributions of maintenance and production to the total requirement. When animal production rate is low, maintenance contributes more, resulting in more feed required per kg product and consequently in more emissions. In meat producing animals the efficiency is also affected by the composition of the meat, the amount of energy required to produce fat being much higher than for lean tissues. In the case of pig production we can estimate from the results of French farms that, compared to the average performing farms, GHG emission is reduced or increased by about 7% in the 30% best- and 30% worst-performing farms, respectively. This means that all the practices, including genetic, nutrition, reproduction or health improvement, that result in the improvement of feed efficiency are potential ways to reduce GHG emissions per unit of product. But maximal feed efficiency does not always means maximal production or maximal economic efficiency.

The composition of the feed has been shown to influence enteric fermentation and emission of  $\text{CH}_4$  from the rumen or the hindgut. In monogastric animals, although some improvements may be expected, the effect is limited because of the rather low contribution of enteric  $\text{CH}_4$  to total emissions (less than 5%) and because the possible variation in diet composition is limited. In ruminants the effect of feed composition is much higher. Methane emission (as a percentage of energy intake) decreases when feeding level increases or when digestibility of the ration is improved. Consequently, as indicated by the equations proposed by Giger-Reverdin et al. (2000),  $\text{CH}_4$  production in the rumen decreases when the proportion of concentrate in the ration increases. The composition of the diet also affects the excretion of N and organic matter, which both will affect the emission of GHG ( $\text{N}_2\text{O}$  and  $\text{CH}_4$ , respectively) during manure storage and spreading. As a consequence, improving the composition of the diet to decrease N excretion, which is often proposed to reduce eutrophication ( $\text{NO}_3^-$ ) and acidification ( $\text{NH}_3$ ) impacts, might also be of interest for the reduction GHG. In monogastric animals, the use of synthetic amino acids (SAA) and phase feeding have been shown be very efficient ways to reduce N excretion (Dourmad and Jondreville, 2007). However to evaluate the real impact of changing the composition of the diet on GHG emission it is necessary to consider the effects on the whole system. For instance increasing the incorporation of SAA in pig diets will result in a reduced incorporation of soybean or rapeseed meal and an increased incorporation of cereals. LCA allows taking all these effects into account (van de Werf et al., 2005). In this context the impact of three scenarios of feed choice was studied by Strid Eriksson et al. (2005). The scenarios differed in the origin of the protein fraction, either imported soybean meal, locally produced peas and rapeseed cake or SAA. GHG emission was the lowest for the pea diet, the highest for the soybean meal diet and intermediate for the SAA diet. In ruminants the real impact of modifying the diet is even more difficult to assess. For instance feeding cows on pasture, which tends to increase enteric production of  $\text{CH}_4$  compared to cereals based diets, induces drastic changes in manure management, most of the excreta being spread by the cows on the fields, and in mechanisation and use of fertilizers. As a consequence GHG emissions associated to the management of manure and the production of feed are reduced. This could explain why GHG emissions in outdoor pasture-based systems (Basset-Mens et al, 2007) in New-Zealand (about 800 kg eq  $\text{CO}_2$  / t milk) are lower than in indoor cereals based systems (about 1300 kg eq  $\text{CO}_2$  / t milk) in the Netherlands (Thomassen et al., 2008), although the opposite was expected when only enteric  $\text{CH}_4$  was considered.

GHG emission from manure has an important contribution to total emission and offers mitigation opportunities. GHG emitted from manure are mainly  $\text{CH}_4$  and  $\text{N}_2\text{O}$ . Methane is produced in anaerobic conditions and is the main GHG emitted from liquid manure. The intensity of production depends mainly on manure organic matter and on temperature and duration of storage. This means that systems with long term storage of liquid manure indoors or outdoors at high ambient temperature will result in much higher  $\text{CH}_4$  emission. The production of nitrous oxide requires aerobic conditions that can be found in solid manure or during the spreading of liquid manure, especially on wet soils. Methane may also be emitted from anaerobic zones in solid manure. This means that, depending on litter management, more  $\text{CH}_4$  or more  $\text{N}_2\text{O}$  will be emitted. Rigolot et al. (2007) estimated that, compared to liquid slurry, the use of straw or sawdust litter bedding in pig production resulted in 120% increase of GHG emission from manure. This originated from an increased emission of  $\text{N}_2\text{O}$  which was only partially compensated by a decreased  $\text{CH}_4$  emission. However these results are highly sensitive to the management of the litter (Hassouna et al., 2005). For instance in litters from ruminants  $\text{CH}_4$  seems to remain the main contributor to GHG suggesting that conditions are more anaerobic. Consequently, as regard to GHG

emission it seems that litter-based systems should not be recommended, but other dimensions have also to be considered in that choice, such as animal health and welfare which are generally improved in these systems. For liquid slurry the main mitigation options are reducing storage duration, especially in hot conditions, the treatment of manure and improved spreading techniques. In this context a rapid removal of the slurry followed by an anaerobic digestion appears a very efficient way to reduce, or even nearly suppress, not controlled CH<sub>4</sub> emission during storage. Moreover this process results in the production of renewable energy. In the case of ruminants, raising the animals on pasture is an efficient way to reduce CH<sub>4</sub> emission from manure, because storage is suppressed.

### Implications

Greenhouse gas emission in animal production is highly variable between and even more, within production systems. This is not surprising, because this criterion has never been considered in the optimisation, or the management, of animal production systems. Many mitigation strategies have been identified and are already available. New technologies can also be expected in the future. In this context it seems important to develop on-farm evaluation tools, based on farm modelling, to assist decision. More research is also needed to better evaluate the emission of GHG, especially N<sub>2</sub>O, in alternative production system.

### References

- Basset-Mens C, Ledgard S, Boyes M 2007. Eco-efficiency of intensification scenarios for milk production in New Zealand. *Ecological Economics*. doi:10.1016/j.ecolecon.2007.11.017.
- Basset-Mens C, van der Werf H 2005. Scenario-based environmental assessment of farming systems: the case of pig production. *Agriculture, Ecosystems & Environment* 105, 127-144.
- Basset-Mens C, van der Werf H, Durand P, Leterme P 2006. Implication of uncertainty and variability in the life cycle assessment. *International Journal of Life Cycle Assessment* 11, 298-304.
- Carlsson-Kanyama A 1998. Energy consumption and emissions of greenhouse gases in the life-cycle of potatoes, pork meat, rice and yellow peas. Technical report 26 ISSN1104-8298. Department of Systems Ecology, Stockholm, Sweden.
- Cederberg C 2002. Life cycle assessment of animal production. PhD Thesis. Department of Applied Environmental Science, Göteborg University, Sweden.
- Cederberg C, Flysjö A 2004. Life cycle inventory of 23 dairy farms in south-Western Sweden. In: SIK report n° 728, SIK, Göteborg, Sweden.
- Cederberg C, Mattson B 2000. Life cycle assessment of milk production – a comparison of conventional and organic farming. *Journal of Cleaner Production* 8, 49-62.
- Dalgard R, Halberg N, 2005. Life cycle assessment of Danish pork. In: *Green Pork Production*, ed. INRA, Paris, 25-27 May 2005.
- Dourmad JY, Jondreville C 2007. Impact of nutrition on nitrogen, phosphorus, Cu and Zn in pig manure, and on emissions of ammonia and odours. *Livestock Science*, doi:10.1016/j.livsci.2007.09.002.
- Giger-Reverdin S, Sauvant D, Vermorel M, Jouany J-P 2000. Empirical modelling of methane losses from ruminants. *Rencontres Recherche Ruminants*, 7, 187-190.
- Haas G, Wetterich F, Köpke U 2001. Comparing intensive and organic grassland farming in southern Germany by process life cycle assessment. *Agriculture Ecosystems & Environment* 83, 43-53.
- Hassouna M, Robin P, Texier C, Ramonet Y, 2008. NH<sub>3</sub>, N<sub>2</sub>O and CH<sub>4</sub> emission from pig-on-litter systems. In: *Green Pork Production*, ed. INRA, Paris, 25-27 May 2005.
- IPCC, 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme, Egglestone, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (eds.). Institute for Global Environmental Strategies, Hayama, Japan. Available at <http://www.ipcc-nggip.iges.or.jp>.
- Rigolot C, Espagnol S, Hassouna M, Dourmad JY 2007. Modelling of manure production by pigs. Effect of feeding, storage and treatment on manure characteristics and emissions of ammonia and greenhouse gases. 58th annual meeting of the European Association for Animal Production (EAAP). Dublin, 26-29 August 2007.
- Roger F, van der Werf H, Kanyarushoki C 2007. Systèmes bovins lait bretons : consommation d'énergie et impacts environnementaux sur l'air, l'eau et le sol. *Rencontres Recherches Ruminants* 14, 33-36.
- Steinfeld H, Gerber P, Vassenaar T, Castel V, Rosales M, de Haan C 2006. *Livestock long shadow. Environmental issues and options*. Ed. FAO (2006), Rome, 390 pp.
- Strid Eriksson I, Elmquist H, Nybrant T 2005. Environmental system analysis of pig production. *International Journal of Life Cycle Assessment* 10, 143-154.
- Thomassen MA, van Calster KJ, Smits MCJ, Iepema GL, de Boer IJM 2008. Life cycle assessment of conventional and organic milk production in the Netherlands. *Agricultural Systems* 96, 95-107.
- Van der Werf H, Petit J, Sanders J 2005. The environmental impact of the production of concentrated feed: the case of pig feeding in Bretagne. *Agricultural Systems* 83, 153-177.