Environmental improvement of pig production: construction and assessment of eight models of pig farms for the future

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ABSTRACT

In a context where husbandries are questioned on their environmental impacts, optimized systems for the future should be devised to provide the milestones. Eight pig systems were constructed by experts by considering the use of best available techniques (BAT), the modernization of buildings and the improvement of technical performances. The kilogram of pig produced from each optimized system was assessed at farm gate using Life Cycle Assessment (LCA) and the results were compared to an average current pig system in conventional production. The results indicate a reduction of impacts which could reach respectively 39, 43, 26, 26 and 45% for climate change, acidification, eutrophication, land occupation and energy use. The implementation of BATs is limited by their cost. Husbandries should improve their technical performances more than those of the 10% best current husbandries to maintain the current cost of production.

Keywords: future models, pig farms, environmental optimization, LCA

1. Introduction

In a context where husbandries are questioned on their environmental impacts (Petit and van der Werf 2003 ; Krystallis et al. 2009), environmental assessments of pig systems are needed in order to inform makers on the recent situation and to initiate improvements. The results must concern different environmental impacts in order to promote a sustainable evolution by limiting the transfer of pollution. The assessments must also be explained under the agricultural practices which devise possibilities of action for the farmers. Best available techniques (BAT) are formalized and recommended to farmers (Bref 2003). Each one is efficient on at least one major environmental flux and concerns a specific part of the farm (building, manure storage, spreading). Pig systems applying these BATs have been assessed by LCA regarding different feeding strategies (Garcia-Launay et al. 2014) or different manure managements (Prapaspongsa et al. 2010). This study proposes to assess pig systems considering an environmental optimization applied on the whole life cycle of pig production. The purpose is to reach the possible global gain. Because the BATs could not all be applied on one farm (some of them concern the same part of husbandry and can't substitute for each other; costs also represent a limit), priorities must be found in improving pig husbandries. It results in a combination of BATs which could differ from one system to another. This study built eight configurations which resulted in eight models of future pig production systems. Environmental and economic assessments were performed among those systems to evaluate the improvement and its applicability.

2. Methods

2.1. Construction of eight models with an environmental optimization

Eight models of pig systems were constructed for the next 10-15 years by 35 experts with a goal of environmental optimization (Table 1). Experts from administration, research and industry were individually interviewed. They bring complementary skills which are necessary to devise sustainable models of production for the future. The experts took care of different environmental aspects (reduction of impacts on water, air and soil) in the regulation context, but also economic and social aspects (competitiveness, income, quality of life and labor). Their expertises enabled decisions to be made for each system of a combination of BATs.

Table 1. Characteristics of the eight optimized models on the environment

Logics	**←--------Combination of pig and crop production--------→**			**←--------Specialized production--------→**				**Outsourcing of farrowing activity**
Models	**1a**	**1b**	**1c**	**2a**	**2b**	**2c**	**2d**	**3**
Size of the pig unit	175 sows – 200 ha	225 sows – 225 ha	250 sows – 120 ha	475 sows – 70 ha	←--------1000 sows – 80 ha--------→			900 sows – 100 ha
Location in an area with high animal density			Yes		←--------Yes--------→			
Mode of housing	Straw litter for sows and fattening pigs, open building with natural ventilation	←--------Closed building, slatted floor and dynamic ventilation--------→						
Pig feeding strategy	←--------Feed production on the farm, use of feedstuffs produced on the farm, use of soy meal not linked to deforestation, substitution of a part of wheat and soy meal by pea--------→							Purchase of feeds
Manure management	Composting manure, spreading manure + exportation	Spreading slurry + small biogas plant at the farm with slurry and intermediate crops with energy value	Phase separation by a centrifugal decanter to reduce the excess of phosphorous + spreading the liquid fraction + exportation of the solid fraction	Spreading slurry + exportation	Biological treatment with centrifugal decanter. Spreading of the liquid fraction, exportation of the solid fraction and the sludge	V scraper in the fattening building. Exportation of the solid fraction. Spreading of the liquid fraction	Spreading slurry + participation to a large biogas plant for the excess slurry	Spreading slurry + exportation
Best available techniques applied		←--------Bioscrubber--------→						
		←--------Cover of the slurry pit--------→						
			←--------Energy efficient equipments--------→					
		Use of the heat produced by methanization to heat the buildings		Flare for the storage				

The eight pig models correspond to three logics of production which were identified for future innovative and competitive husbandries by Roguet et al. (2009): the combination of pig and crop production (3 models), the specialized production of pigs (4 models) and the outsourcing of farrowing activity (1 model). Other distinguishing criteria concerned the type of production (7 models with standard pork quality and 1 model 1a with improved quality) and the strategy of manure management in relation to the link of livestock to land (conventional storage and spreading, biogas plant, aerobic treatment). The model with improved quality was chosen to be smaller than the other by its size, with more autonomy for the feeding strategy and the manure management, and with the use of straw for the pigs. It corresponds to a model which is often well received by society as it has an environmental consideration. The level of access to land is determinant for manure management and depends on the agricultural area of the farm but also on its location. For this reason some models defined for territory with a high density of animal production treat their manure for abatement and exportation (1c, 2b, 2c and 2d). For the other models, spreading was considered to be the best way to valorize the manure.

2.2. LCA assessment

The kilogram of live pig at farm gate for the eight models was assessed by Life Cycle Analysis (LCA). The environmental impacts were: Climate change in kg CO_2eq (CC), Eutrophication in kg PO_4^{3-}eq (E), Acidification in kg SO_2eq (A), Energy consumption in MJ (EgC) and Land occupation in m^2year (LO). The LCA scope included the production and supply of inputs, the construction of the building, and the pig breeding (Figure 1). Concerning manure management, the system boundaries integrated the avoidance of the production and application of mineral fertilizer which would be applied on crops if manure were not spread, as described by Nguyen et al. (2010).

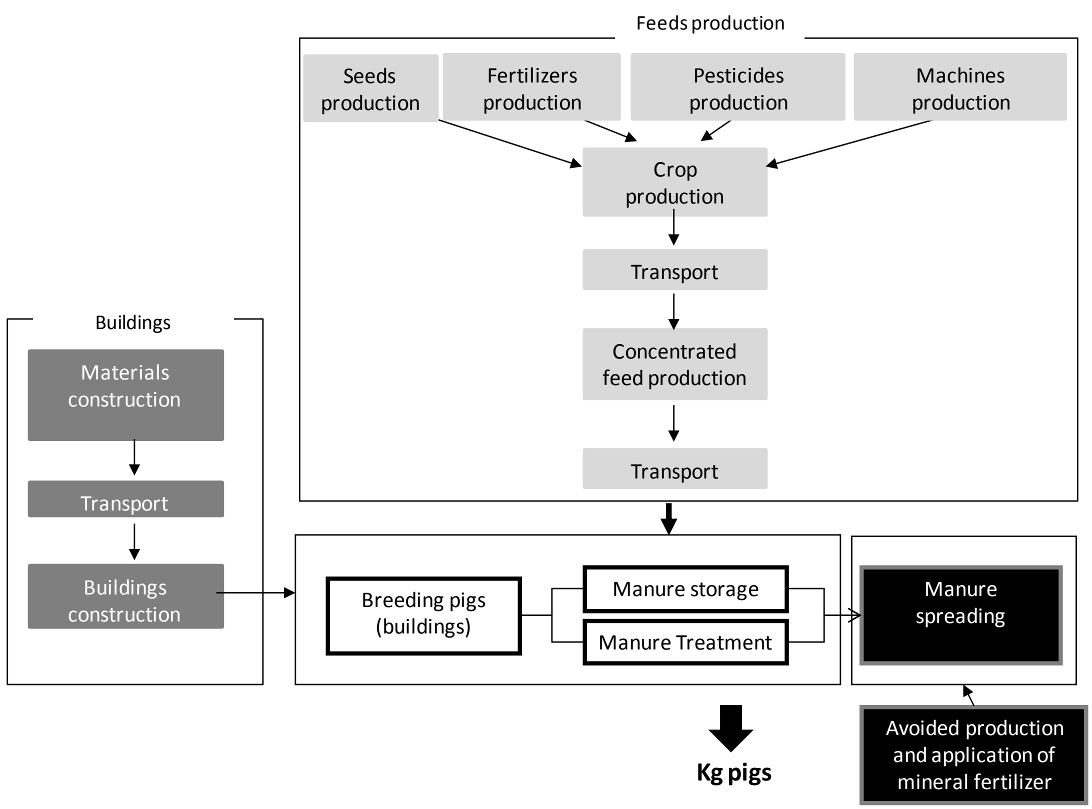

Figure 1. LCA perimeter

In order to measure the reduction of impacts, the optimized models were compared to an average current pig system defined by Espagnol et al. (2012), with the same LCA methodology. The reference system is a fully slatted floor with a classic management of manure (storage under the pigs in the building, external storage in a pit and spreading). Its technical performances are given in Table 5 (husbandries with less than 500 sows). No BAT was considered for this current average system. Its impacts per kilogram of live pig at farm gate are given in Table 4 and correspond to those of a current pig system with less than 500 sows.

Table 2. Models used in the LCI assessment of the optimized systems

Substance emitted / Resource consumed	Source of emissions / consumer of resource	Literature reference for model used
Ammonia (NH_3)	Animal excretion of nitrogen Emissions of NH3 (buildings, storage)	CORPEN 2003 CORPEN 2003
Combustion gas	CO_2	Ecoinvent® v2
Methane (CH_4)	Animal excretion of VS Emissions from manure management Emissions from enteric fermentation	IPCC 2006 Tier 2 IPCC 2006 Tier 2 IPCC 2006 Tier 1
Dinitrogen oxide (N_2O)	Emissions of N_2O (buildings, storage)	IPCC 2006 Tier 2
Phosphorus	Animal excretion of phosphorous Phosphorous losses	CORPEN (2003) Nemecek (2007)

Table 3. Efficiency of the BATs considered in the optimized systems issued from Bref (2003) and national publication (Guingand et al. 2010)

Best available practices	Application scale	Environmental flux	Efficiency at application scale (% abatement)	Cross effects
Bioscrubber	Building	NH_3	50%	Increase of the nitrogen content in the manure
Pit cover	Manure storage	NH_3	70%	Reduction of the manure volume, increase of the nitrogen content in the manure
V scraper	Fattening building	CH_4 N_2O NH_3	100% 49% 40%	Increase of the nitrogen content in the manure
Flare	Storage	CH_4	100%	
Heat pump	Buildings	Energy consumption	65%	
Heat exchanger	Buildings	Energy consumption	30%	
Niches with underfloor heating	Farrowing building	Energy consumption	50%	
Niches for weaned piglets	Buildings	Energy consumption	75%	
Centralized ventilation	Buildings	Energy consumption	60%	
Efficient fan	Buildings	Energy consumption	50%	
Control of the ventilation rate	Buildings	Energy consumption	30%	
Trailing shoes, injector	Spreading	NH_3	Respectively 35% and 70%	
Biogas plant	Treatment	CH_4 and energy	Destruction of 100% CH_4 + production of energy sold and heat used for the building	Energy consumption for the biogas plant. Increase of the nitrogen and phosphorous content in the digestate to spread when there is the use of external inputs (2d)
Improvement of the production of crops	Feeds	Reduction of all the impacts	8.8% on the CC, 3.9% on A, 2.1% on E, 4.6% on EgC and 2.9% on LO	
Reduction of the excretions (N and P)	Excretion	N and P excretions	5% for N and P excretions of systems 1a, 1b and 1c 10% for N and P excretions of the others systems	Reduction of the N emissions of the manure and reduction of the area needed to spread the manure

For the Life Cycle Inventory (LCI) of the optimized models, some improvements were considered comparing them to the current situation. The technical performances of the optimized systems correspond to the 10% of the best French pig husbandries (Table 5). A reduction of nitrogen and phosphorous excretion was applied (Table 3) compared to the current situation considering pretreatment of the feedstuffs and multiphase feeding. The soy meal incorporated in the feeds was considered coming from Brazil but from a location not linked to deforestation (Mosnier et al. 2011). An increased incorporation of pea (10%) into the feeds was chosen instead of a part of wheat (5%) and soy meal (5%). An improvement in crop production was also taken into account based on the result of a prospective analysis by the French agricultural ministry (2011). The efficiencies of the BATs at their application scale are given in Table 3. The models used for LCI are given in Table 2.

For the models with biogas plant (1b and 2d), the emissions linked to the digester and pre and post storage were allocated between the kilogram of pig and the kWh produced considering the energetic content of the inputs in the digester.

3. Results

The results of LCA for optimized system and the baseline scenario are given in Table 4. The optimized models compared to the baseline show reduction of impacts that could achieve up to 39%, 43%, 26%, 26% and 45% for the respective impacts of CC, A, E, OS and EgC.

Table 4. LCA results of optimized pig systems

	LCA results / kg of live pig				
	CML, 2001				Recipe
	Climate change (kg CO_2eq)	Acidification (kg SO_2eq)	Eutrophisation (kg PO_4eq)	Land occupation (m^2.year)	Energy consumption (MJ)
System 1a	2.49	0.047	0.023	4.96	11.57
System 1c	1.54	0.029	0.018	6.49	10.07
System 2a	1.33	0.026	0.017	6.71	9.65
System 2b	1.88	0.027	0.017	4.72	11.97
System 2cb	1.51	0.026	0.017	6.34	10.21
System 3	1.69	0.027	0.018	6.07	11.33
System 1b	1.41	0.026	0.017	6.91	8.95
System 2d	1.31	0.025	0.017	6.21	8.98
Baseline	*2.14*	*0.044*	*0.023*	*6.46*	*16.29*

The reduction of impacts of a kilogram of pig at farm gate is performed mainly during the production of the feed and during the breeding of the pigs.

The improvement of the feeding strategy reduces the impacts among the optimized systems of a range from 18 to 20%, 4 to 6%, 5 to 8%, 2% and 11 to 21% respectively for CC, A, E, LO and EgC. It is due both to the improvement of the technical performances of the pigs and also to the reduction of impacts during the crops production.

The use of BAT in the pig husbandries reduce the impacts for all the optimized systems except 1a from 7 to 19%, 29 to 37%, 12 to 16% and 15 to 23% for respectively the CC, A, E and EgC.

The impacts CC, A and E of the system1a are higher than the other systems despite the fact that BATs are used. This is due mainly to the use of litter in the pig buildings which emitted N_2O (impact on CC) and to the fact that techniques like bioscrubber could not be used in natural ventilation conditions (emissions of NH_3 are not abated and have impact on acidification).

Concerning the spreading of the manure, the difference among the optimized systems and by comparison to the current husbandry shows less difference except for systems 1a, 2b and 2c. The systems 1a and 2b abate nitrogen with respectively composting and biological treatment. The content of nitrogen in the manure to spread is also reduced and changes the comparison with mineral fertilization.

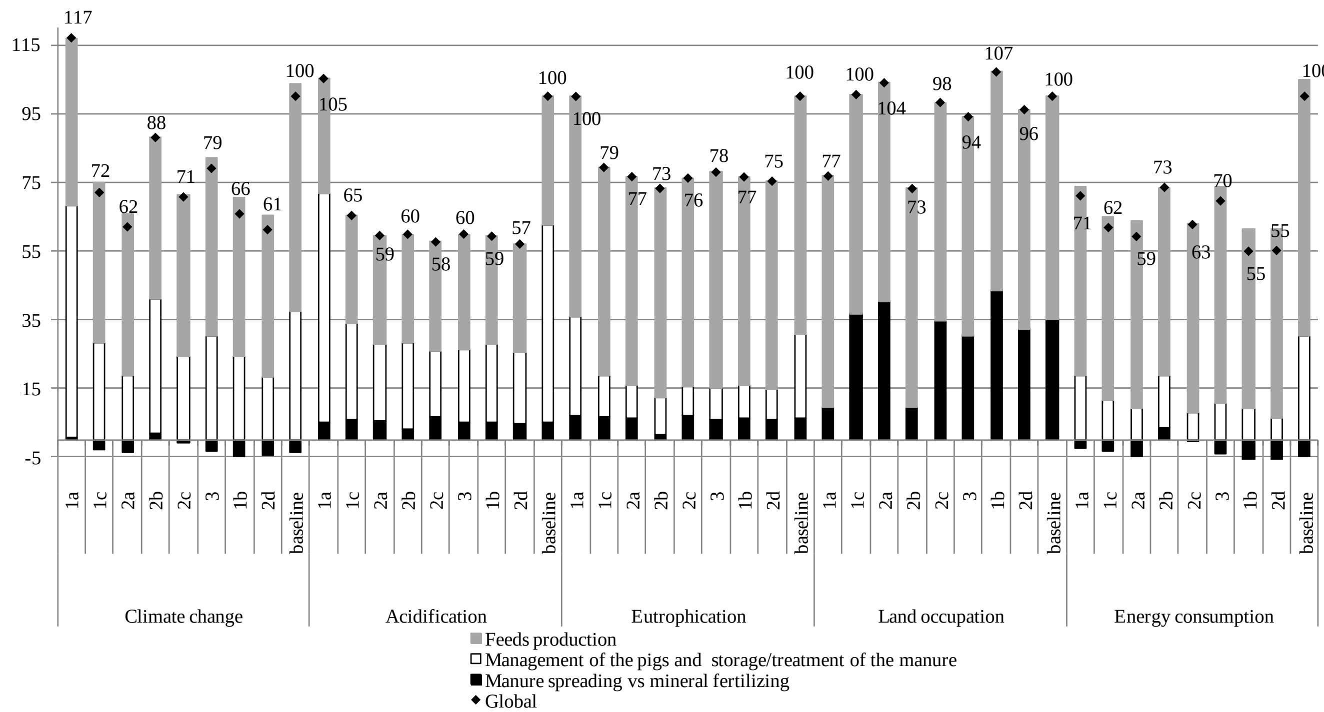

Figure 2. Relative result of LCA in % for the optimized systems compared to the baseline scenario with the importance of three main steps (1/ production and supply of the feeds, 2/ husbandry with the breeding of the pigs and manure management in the building and during the storage/treatment of the manure, 3/ organic fertilization compared to mineral fertilization).

4. Discussion

The result indicates the cumulative reduction of impacts which could be reached by the application of BATs in pig production at farm gate. The next step is to advise the farmers in order to encourage them to go from the current husbandries to the optimized ones. The adoption of BATs will depend on the information they will find. The benefit of BATs at the scale of the pig life cycle is useful and complementary to the efficiency at the application scale because it enables the relative interest of BATs to be measured.

Figure 3 gives the example of three BATs for the reduction of ammonia emissions in pig husbandries. The efficiency at application scale indicates that the pit cover is the most efficient with 70% of abatement versus respectively 50% and 40% with the bioscrubber and the V scraper (Table 3). The reduction rate obtained at life cycle scale shows that the bioscrubber is the BAT which can most reduce the acidification impact. This scale has the advantage of taking into consideration the relative importance of the emissions on which the BAT is applied. It makes it possible to compare different BATs used on different parts of the husbandry (i.e. building, storage …).

Even if the use of BATs indicates possible reduction of the environmental impacts for pig husbandries at LCA scale, the capacity of the current pig units to invest in these is limited because of their costs. The comparison between the three BATs could be completed by analyzing the cost of the reduction of 1 kg SO_2eq/kg of pig (Figure 3). This expression of the results points to the pit cover as being the best in terms of efficiency and the relative cost.

In the future, the cost of BATs could be a limit to their adoption. The bigger units should cope better because they are more likely to be trusted by the banks because of their size and their technical performances. The costs of BATs have been expressed for four types of husbandries: with less than 500 sows, with more than 500 sows, 20% of the best husbandries and 10% of the best husbandries (Table 5).

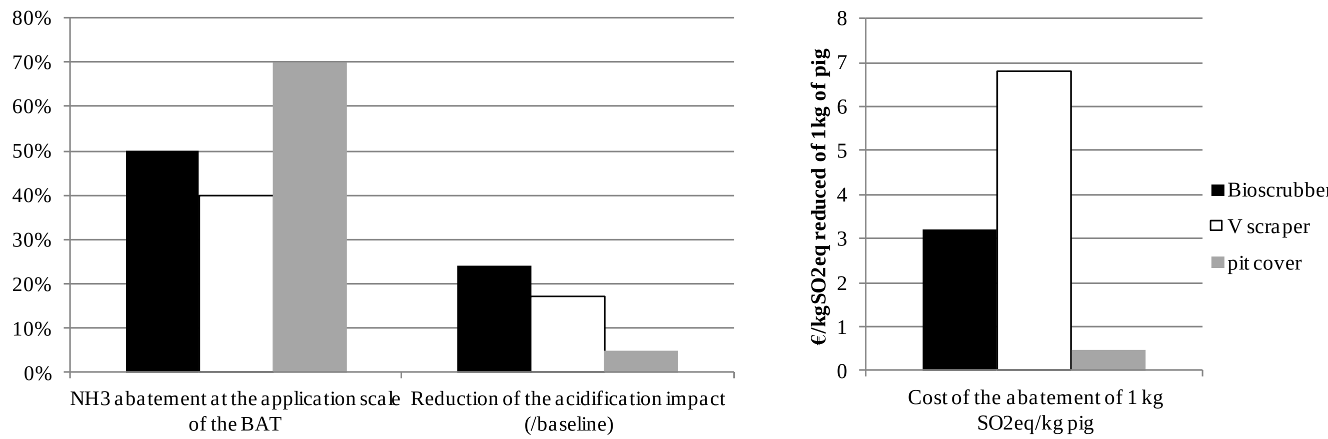

Figure 3. Relative interest for BAT – comparison for bioscrubber, V scrapper and pit cover of the relative interest considering efficiency at application scale (%), efficiency at life cycle scale for acidification (%), the cost of a reduction of 1 kg of SO_2eq per kilogram of pig (€/kg SO_2eq reduced).

For the husbandries with less than 500 sows (representative of current farms with buildings half depreciated), the average cost without BAT is 1.278 €/kg carcass, and goes from 1.359 to 1.438 €/kg carcass with the use of BATs. The BATs without any technical improvement cause an increase in the cost of 0.08 € - 0.15 €. As chosen for the optimized systems of this study, the husbandries of the future might have better technical performances but also increased costs due to necessary investments in modernizing the buildings. With a new building depreciated to 25%, the costs range from 1.300 to 1.453 €/kg carcass depending on the hypothesis made on technical performances. It should be higher than those of the best 10% to access a cost like the current one. This indicates that the implementation of these best practices in existing pig farms is hampered by the additional cost incurred, while the pig price paid to producers is determined in a very liberal and competitive European pig market.

Table 5. Economic assessment of the eight optimized pig systems

	Current pig systems with less than 500 sows*	Current pig systems with more than 500 sows**	20% best husbandries**	10% best husbandries**
Pig produced (/sow/year)	22.34	24.36	25.25	25.94
Weight of fattening pigs (kg)	116.0	116.0	116.7	117.0
Feed conversion ratio (kg /kg)	2.83	2.81	2.73	2.70
Price of fattening pig (€/ton)	184	178	183	183
Working time (h/sow/year)	20	15	15	15
Cost without BAT (€/kg carcass)	1.278	1.314		
Cost with 160€/sow of BAT (€/kg carcass)	1.359	1.384	1.323	1.300
Cost with 315 €/sow of BAT (€/kg carcass)	1.438	1.453	1.389	1.365

*buildings depreciated 50%; ** buildings depreciated 25%

5. Conclusion

This study sheds light on what could be the optimized pig systems for the future by taking into account a reduction of the environmental impacts. BATs have been applied on different parts of the life production of pig including crop production. Important reductions of impacts have been measured and indicate the level of global gain which could be achieved. Different options of BAT combinations could be used and all have results on an impact reduction. This allows the farmers to find the best solution for their system and its location.

The life cycle scale used for the assessment is interesting to measure the relative interest of BATs, and this kind of information is needed by the farmers if they decide to improve their system. The data concerning costs are also critical to the implementation in the field and the study underlines the economic difficulties of applying BATs in current French pig husbandries. The evolution will be correlated by the European pig market on which the price is defined by supply and demand. If all the countries do not decide to invest in BATs, those who do so will be penalized. If the solution is to absorb the additional costs, the improvement of technical performances should be higher than the 10% best current husbandries.

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