Effect of precision feeding on environmental impact of fattening pig production

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Abstract

Various studies have shown that improved feed efficiency is an efficient lever to reduce the environmental impact of pig production. The development of feeders which allow the distribution of different diets, together with new low-cost animal identification technologies and sensors for high-throughput collection of information on animals (body weight, feed intake), should allow the development in practice of individual feeding of fattening pigs in the near future. With this in mind, a modelling approach was used to evaluate the potential of this strategy to reduce the environmental impact of pig fattening. Eight populations of 2000 pigs, fed according to either a conventional two-phase (2P) or a precision feeding (PR) strategy, were simulated using the population version of InraPorc. This was performed for two geographical production contexts (Brazil and France) with two soyabean meal origins (Centre West Brazil, a region with deforestation, and South Brazil, without deforestation). Environmental impacts were evaluated using a cradle-to-farm gate life cycle assessment and were expressed per kg of weight gain. Compared to 2P, PR improved average daily gain and feed efficiency by about 4-5% and reduced feed costs by 7-10%. It reduced nitrogen excretion by about 20%. On average, compared to 2P, the PR feeding strategy reduced environmental impacts for climate change, energy use, eutrophication, acidification and land occupation by 6.1%, 6.9%, 10.3%, 12.7% and 3.5%, respectively. It was concluded that PR appears to be a very interesting strategy for improving economic and environmental dimensions of sustainability in pig production.

Keywords: fattening pig, precision feeding, environmental evaluation, life cycle assessment

Introduction

The environmental impacts of pig production have been debated increasingly in recent years, resulting in a greater focus on identifying and mitigating the environmental degradation they may cause. Better adjustment of nutrient supply to animal requirements (Dourmad and Jondreville, 2007) may be a key factor in improving the efficiency of nutrient retention, reducing excretion and consequently increasing the sustainability of pig production. The development of innovative feeders which allow the distribution of different diets, together with new low-cost animal identification technologies and sensors for high-throughput collection of animal information (body weight, feed intake), should allow the development of individual pig feeding in practice in the near future.

Precision feeding appears to be the most promising approach to improving the efficiency of nutrient use. This technique has been successfully tested on growing-finishing pigs (Pomar et al., 2009; Andretta et al., 2014). The strategy is to predict the expected performance of each individual pig according to previous real-time measurements of feed intake and body weight, and to feed it with a ration which provides the amount of nutrient required to achieve the expected performance (Hauschild et al., 2012).

In recent years, life cycle assessment (LCA) has been widely used in agriculture (Guinée et al., 2002) and several studies of swine production chains have been conducted (Nguyen et al., 2010, Garcia-Launay et al., 2014). LCA makes it possible to perform an integrated environmental evaluation of the whole production chain, considering the potential impacts associated with the raising of pigs as well as those related to the production of inputs (e.g. the feed) and the disposal of waste (e.g. the manure produced).

The aim of this study was thus to use a simulation approach to evaluate the potential for precision feeding of fattening pigs, compared to phase feeding, in two different production contexts, in southern Brazil and western France.

Materials and methods

Feeding strategies and feed specifications

The study considered the growing-finishing pig production system, with three different feeding programmes: two phases (2P), four phases (4P) and precision feeding (PR). Two experimental feeds (named A and B) were independently formulated at least cost for each sex (females and castrated males) in each country. Feeds A and B differed in their amino acid and mineral concentrations, with feed A being formulated with a high nutrient density to meet the estimated nutrient requirements at the beginning of the growing period, and feed B formulated with a low nutrient density to meet the estimated nutrient requirements at the end of the finishing period. Feeds A and B were combined according to the feeding programme. In the 2P feeding programme, feeds A and B were combined in the following proportions: 100% and 0% in phase 1, and 42% and 58% in phase 2 for feeds A and B, respectively. In the 4P feeding programme, feeds A and B were combined in the following proportions: 100% and 0% in phase 1, 65% and 35% in phase 2, 42% and 58% in phase 3 and 15% and 85% in phase 4 for feeds A and B, respectively. In the precision feeding strategy, the proportion of feed A and B was calculated each day for each pig according to its expected amino acid requirement (Hauschild et al., 2012). Feeds contained the usual feed ingredients, including industrial amino acids, used in each country and were formulated at least cost using OpenSolver for Excel®, using the mean prices of feed ingredients in Brazil and France for the year 2014.

Pig production

Performance data from experimental studies in Brazil (Monteiro et al., 2017) and France (Brossard et al., 2014) were used to adjust average animal profile parameters for growth and feed intake using InraPorc® software. These profiles were used to calculate, according to InraPorc®, the average nutritional requirement curves for each sex (females and castrated males), these requirements being used for diet formulation. To take account of the variability, the nutrient requirement of the population was calculated as 110% of the mean requirement as generally recommended (Pomar et al., 2009; Brossard et al., 2009). Parameters for growth and feed intake profiles were thus defined for a population of 1000 castrated males and 1000 females for each country, according to the method described by Brossard et al. (2009) using a variance-covariance matrix. Simulations for 2000 pigs (50% females, 50% castrated males) were performed for each feeding scenario in each country in order to determine animal performance, and nutrient balance and excretion.

Life Cycle Assessment

LCA was performed according to Nguyen et al. (2010) and Garcia-Launay et al. (2014). The LCA considered the entire pig farming activity, including crop production, grain drying and processing, production and transport of feed ingredients, feed production at the feed factory, transport of the feed to the farm, growing to finishing pig production, and manure storage, transport and spreading. The pig production system considered was typical of conventional growing-finishing pig farms located in Brittany and southern Brazil. The environmental consequences of manure utilisation were evaluated using system expansion as described by Nguyen et al. (2010). It was assumed, for both countries, that soyabean was produced in Brazil either in the Centre West (CW), a region with recent deforestation, or in the South (SO) where there is no deforestation. For Brazilian crops, the life cycle inventory (LCI) came from Prudêncio da Silva et al. (2010), taking into account the effect of land-use change on carbon release due to conversion of Brazilian forest to cropland. For French crops, the LCI came from a national database developed by French research institutes with data for the environmental impacts of all main ingredients used in animal feeds (Wilfart et al., 2015). Emissions to air during swine production and management of manure were estimated according to Rigolot et al. (2010) and IPCC (2006). The following potential impacts of pig production were considered: climate change (CC, kg CO_2-eq.), eutrophication potential (EP, g PO_4-eq.), acidification potential (AP, g SO_2-eq.), terrestrial ecotoxicity (TE, g 1,4-DCB-eq.), cumulative energy demand (CED, MJ), and land occupation (LO, m^2.year). The CC was calculated according to the 100-year global warming potential factors in kg CO_2-eq. Impacts were calculated at the farm gate and the functional unit considered was one kg of body weight gain (BWG) over the fattening period.

Results and discussion

Animal performance

Simulated pig performance and the results for nitrogen excretion are presented in Table 1. Average dietary crude protein (CP) content was significantly affected by country and feeding programme. Compared with 2P, the PR feeding programme reduced dietary CP by 7% and 13% for Brazil and France, respectively. The reduction of CP content was accompanied by a decrease in feeding cost (-7 and -8% between 2P and PR programmes for Brazil and France, respectively). In both countries, ADG was affected by the feeding programme: the highest growth performance was obtained for PR (946 g/d on average) and the lowest (914 g/d on average) for 4P. Similar effects were observed for feed conversion ratio, which was lower for PR than for 4P (2.66 vs. 2.75 kg/kg). Compared with the 2P programme, the PR programme reduced nitrogen excretion by 19 and 21% in Brazil and France, respectively, 4P feeding programmes being intermediate.

Acidification and eutrophication potential

With soyabean from SO, the AP values for the different feeding programmes ranged from 53.9 to 60.2 g SO_2-eq. per kg BWG in Brazil and from 40.8 to 47.1 g SO_2-eq. per kg BWG in France (Table 1). With soyabean from CW the values increased slightly to 54.7 to 61.3 g SO_2-eq. per kg BWG in Brazil and 41.3 to 48.0 g SO_2-eq. per kg BWG in France. The lowest AP impact was obtained for

PR, both for soyabean from SO and CW, with on average about a 12% reduction in AP impact for PR compared to 2P and 4P, which did not differ from each other. The EP values for the feeding programmes ranged from 15.6 to 17.5 g PO_4-eq. per kg BWG, with no difference between countries and with similar results for soyabean from SO and CW (Table 1). The lowest EP impact was obtained for PR in both countries (mean of 15.6 g PO_4-eq. per kg BWG) and the highest for 2P and 4P which did not differ (mean of 17.2 g PO_4-eq. per kg BWG). Since nitrogen contributes to eutrophication and to acidification through ammonia emissions (Guinée et al., 2002), the AP and EP impacts were reduced in both countries by increasing the number of feeding phases and to a higher extent by precision feeding. This was not surprising because these strategies reduce nitrogen excretion and, consequently, also reduce NH_3 emissions from animal housing, manure management and field application.

Table 1. Performance and environmental impacts of growing-finishing pigs fed with different feeding strategies, in 2-phase (2P), 4-phase (4P) or individual precision feeding (PR)

	Brazil[1]			France			Stat Sign.[2]		
	2P	4P	PR	2P	4P	PR	C	S	CxS
CP, g/kg	145^{a}	139^{b}	135^{b}	158^{a}	149^{b}	137^{c}	**	***	***
ADG, g/d	842^{ab}	830^{b}	878^{a}	909^{ab}	899^{b}	915^{a}	***	*	
FCR, kg/kg	2.75^{b}	2.79^{a}	2.64^{c}	2.69^{b}	2.72^{a}	2.69^{b}	**	***	***
Cost, €/kg ADG	0.54^{a}	0.53^{a}	0.50^{b}	0.60	0.58	0.55	***	***	
N exc., kg/pig	3.39^{a}	3.25^{a}	2.75^{b}	3.69^{a}	3.43^{a}	2.91^{b}	***	***	
LCA per kg BWG (SO)[3]									
CC, kg CO_2 eq.	2.40^{a}	2.43^{a}	2.30^{b}	2.33^{ab}	2.35^{c}	2.32	**	***	*
CED, MJ	13.4^{b}	13.5^{a}	12.9^{b}	12.7^{a}	12.6^{a}	12.1^{b}	***	***	
AP, g SO_2 eq.	60.2^{a}	59.6^{a}	53.9^{b}	47.1^{a}	45.3^{a}	40.8^{b}	***	***	
EP g PO_4 eq.	17.5^{a}	17.3^{a}	15.7^{b}	17.2^{a}	16.8^{a}	15.7^{b}		***	
LO, m^2.year	2.39^{a}	2.40^{a}	2.26^{b}	3.78	3.82	3.79	***	**	**
LCA per kg BWG (CW)[3]									
CC, kg CO_2 eq.	2.81^{a}	2.80^{a}	2.61^{b}	2.65^{a}	2.61^{a}	2.48^{b}	***	***	
CED, MJ	15.5^{a}	15.4^{a}	14.5^{b}	13.8^{a}	13.5^{a}	12.7^{b}	***	***	
AP, g SO_2 eq.	61.3^{a}	60.5^{a}	54.7^{b}	48.0^{a}	46.0^{a}	41.3^{b}	***	***	
EP g PO_4 eq.	17.4^{a}	17.2^{a}	15.6^{b}	17.1^{a}	16.8^{a}	15.6^{b}		***	
LO, m^2.year	2.35^{a}	2.36^{a}	2.22^{b}	3.75	3.80	3.77	***	**	**

[1]Within-country means followed by same or no letter do not differ ($P > 0.05$)
[2]Statistical significance of effects of Country (C), Feeding Strategy (S) and their interaction (CxS), * P<0.05., ** P< 0.01, *** P<0.001
[3]Life Cycle Assessment with soyabean from Centre West (CW) or South (S) Brazil

The distribution of EP impact among pigs is presented in Figure 1 which shows a non-normal distribution for phase feeding, indicating that the highest performing pigs (i.e. those with the lowest impact) are not able to achieve their expected performance, probably because of insufficient amino acid supplies during the transition periods. With the change in diet composition, this explains the lower average EO impact obtained with precision feeding.

Climate change potential

With soyabean from SO, the average CC values for the different feeding programmes ranged from 2.30 to 2.40 kg CO_2-eq. per kg BWG in Brazil and from 2.32 to 2.33 kg CO_2-eq. per kg BWG in France (Table 1). When soyabean meal from CW was used, CC values increased to 2.61 to 2.81 kg CO_2-eq. per kg of BWG in Brazil and to 2.48 to 2.65 kg CO_2-eq. per kg BWG in France. The impact on CC did not differ between the 2P and 4P feeding programmes. Conversely, the PR feeding programme significantly reduced the CC impact, with values on average 3% and 6% lower than for the two other strategies, for soyabean from SO or from CW, respectively. The effect of the PR feeding programme on CC was thus more pronounced with soyabean from CW. This indicated that the effect of phase feeding on CC may depend on the origin and the amount of soyabean, in agreement with the studies of Eriksson et al. (2005) and Garcia-Launay et al. (2014).

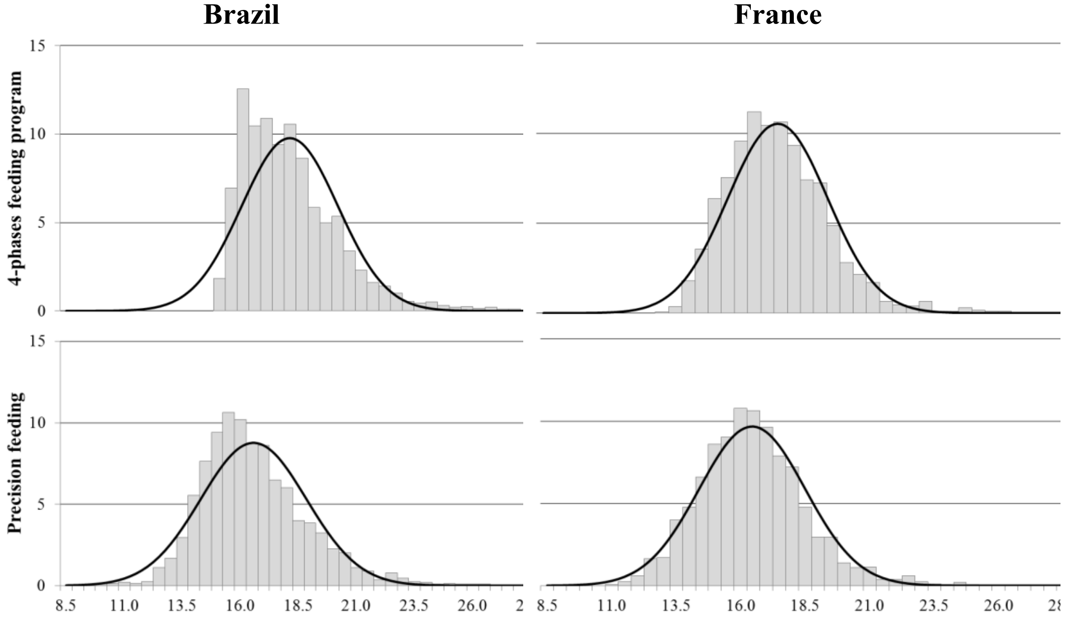

Figure 1. Frequency of distribution of pigs (%) and normal curve for eutrophication potential, according to the feeding programme and country (soyabean from SO).

Cumulative energy demand

With soyabean from SO, the CED values for the different feeding programmes ranged from 12.9 to 13.4 MJ-eq. per kg of BWG in Brazil and from 12.1 to 12.7 MJ-eq. per kg of BWG in France. With soyabean from CW, the values increased to 14.5 to 15.5 MJ-eq. per kg BWG in Brazil and to 12.7 to 13.8 MJ-eq. per kg of BWG in France. The lowest CED impact was calculated for PR, with a 4% and 7% reduction in CED impact compared to 2P and 4P, for soyabean from SO and CW, respectively. The possibility of reducing the CED impact by increasing the number of feeding phases was confirmed for diets based on soyabean meal from CW, but not for soyabean from SO. Precision feeding only resulted in reduced CED impact in that situation.

Land occupation

The LO values for the different feeding programmes ranged from 2.22 to 2.39 m^2.year per kg BWG in Brazil and from 3.77 to 3.82 m^2.year per kg BWG in France, with similar results for soyabean from both origins (Table 1). The feeding programme affects LO in Brazil, with the lowest impact for PR which was 6% lower than 2P and 4P, but not in France.

Conclusions

The results of this study indicate that precision feeding would be the most efficient approach for reducing the life cycle impact of pig fattening, whereas the potential of phase feeding programmes depends on the impact considered, soyabean origin and the geographical context of pig production. The benefit of phase feeding for reducing the climate change impact is limited with soyabean from South Brazil, whereas it appears to be an efficient strategy with soyabean from the Centre West. Conversely, potential eutrophication and acidification impacts are largely reduced by phase feeding in a rather similar way in all situations.

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