Life cycle analysis of swine management practices

Prathamesh Bandekar[1,*], Mansoor Leh[1], Rusty Bautista[1], Marty D Matlock[1], Greg Thoma[2], Rick Ulrich[2]

[1] Department of Biological and Agricultural Engineering, University of Arkansas, Fayetteville-AR
[2] Department of Chemical Engineering, University of Arkansas, Fayetteville-AR
[*] Corresponding author. Email: *pbandeka@uark.edu*

ABSTRACT

A comparative Life Cycle Assessment (LCA) of different management strategies in the pork industry was performed to evaluate the impact on global warming potential (GWP) and energy and water use. The management strategies included immunocastration, production without ractopamine, production without antimicrobials, and use of gestation pens. Impacts of each management practice were compared to a common baseline production strategy that represents current production practices. Scope of this study was from cradle through farm gate with a functional unit of 1 kg of live weight at the farm gate. Each scenario was simulated using the Pork Production Environmental Footprint Model, to populate life cycle inventory inputs for SimaPro V7.3 (Pre' Consultants, The Netherlands). The results showed that compared to the baseline, use of gestation pens and production of immunocastrated pigs had lower GWP, energy use and water use. Production without ractopamine and antimicrobials increased GWP, energy use, and water use.

Keywords: Swine management practices, Life cycle assessment,

1. Introduction

There is a demand for changes to some of the management practices prevalent in the swine industry Florida, in 2002, banned use of sow gestation crates and similar ban was imposed on the swine industry in Arizona in 2006 (Mench 2008). A survey conducted by the Rutgers University in 2003 revealed that between 74 and 83% of the participants disagreed with practices such as tail docking of cows and pigs without analgesics and confining gestating sows (Mench 2008). Heeding its consumers, (Smithfield Foods) decided in 2007 to phase out gestation stalls on company-owned farms over next 10 years and replace them with pens.

Life Cycle Assessment (LCA) is an effective tool for performing trade-offs associated with alternate management strategies. This project supports the goal of the National Pork Board environment committee to: optimize management practices to enable producers to make informed management practice decisions to continually improve their farms; provide pork producers with the information and education they need to evaluate and implement appropriate management practices on their farms; and educate customers about the environmental and sustainability consequences of their purchase decisions.

The objective of this study was to quantify differences or establish the absence of differences in the global warming potential (GWP), cumulative energy demand, and water consumption between current practices and proposed alternates. All the scenarios were simulated for Wright County, Iowa and a typical meteorological year was used as the simulated climate.

2. Methods

This study analyzed the cradle to farm gate impacts for 5 different management practices (Table 1) with a functional unit of 1 kg live weight at the farm gate was chosen for this study.

Table 1. Proposed alternate management practices

Management strategy	Description
Immunocastration	Use of inmmune-castration methods/product(s)- Improvest®
No ractopamine	Removal of ractopamine (RAC) as a tool to improve growth and production
No GP antimicrobials	Removal of antimicrobials as growth promoters (GP)
No Prev. antimicrobials	Removal of antimicrobials to prevent emergence of herd infection in addition to removal of GP antimicrobials
Pen gestation	Use of pen gestation housing

2.1. Description of Models

Assessment and comparison of different management practices in terms of greenhouse gas emissions, water use and electricity use involved a two-step process. In the first step nursery, grow-finish and sow barns were simulated using Pig Environmental Footprint model (University of Arkansas). The outputs of these simulations were used in the second step for LCA analysis using SimaPro V7.3 (Pre' Consultant, the Netherlands).

2.2. Pig Environmental Footprint model

The growth and feed conversion performance of pigs, resource consumption, and emissions to the environment were simulated using the PPEF model. The model simulates pig growth, feed intake and water consumption, electricity and natural gas use, manure handling, and greenhouse gas emissions over an annual cycle. The PPEF model uses a growth performance model developed by the National Resources Council (NRC) to predict growth and feed consumption of pigs (National Research Council 2012).

2.3. SimaPro LCA model

The SimaPro software platform was used to compare each management scenario to the baseline and for uncertainty analysis. The Ecoinvent database, corrected for US electricity, was used for background processes, and feed production data for the US developed at UA was used for constructing the animal's rations.

2.4. Scenario Description

Each test scenario evaluated only one management practice, where only the key element was changed. A single, typical ration was used for all scenarios to prevent confounding effects of the ration with the practice under evaluation. The last dietary phase in grow-finish barn was formulated to accommodate use of ractopamine by adding 0.05% Paylean 9 (Rikard-Bell et al. 2009, See et al. 2004). It was assumed that pigs have ad libitum access to the water and drinking water consumption, along with cooling and wash water, were simulated in the PPEF model.

2.4.1. Baseline scenario

Each scenario was compared pairwise with the baseline scenario. The baseline scenario included male (barrows) and female pigs in equal numbers and assumed growth promoting antimicrobial (AGP) use in the nursery, preventive antimicrobial use as required, ractopamine use in grow-finish barn, with tail docking and surgical castration of male pigs performed in the lactation barn. The NRC growth model for growing pigs assumes that the maximum protein deposition value (Pdmax) in pig decreases after a certain weight is reached (National Research Council 2012). Paylean-9 was added to the diet in the last phase of feed formulation and at a pig body weight of 96 kg to simulate 28 days on the ractopamine. The average market weight of 125 kg (approx. 275 lbs) (National Pork Board , USDA , USEPA) was chosen for fair study.

2.4.2. Removal of ractopamine (RAC)

Ractopamine is a dietary supplement which improves average daily gain (ADG) and feed efficiency (FE) in finishing pigs (Armstrong et al. 2004, Barbosa et al. 2012, Dunshea et al. 1993, Hinson et al. 2011) and is usually added to the diet during last 28 days in the finishing phase (Hostetler et al. 2012). The final ration phase, without ractopamine, was also altered to include more corn based on recommendations from swine nutritionists. No changes were made to the nursery and sow barn that provided feeder pigs to the grow barn for this scenario.

2.4.3. Antimicrobial use

Antimicrobials are used in animal industry for disease prevention, animal health improvement (Romina Ross et al. 2010), and as growth stimulants (Kiarie et al. 2011). However, antimicrobial use in animal industry has come

under scrutiny due to the concerns about development of antimicrobial resistant strains that could affect human health (Holt et al. 2011). We constructed scenarios to evaluate the impacts associated with reduced use of antimicrobials in pig production. The first scenario assessed impact of eliminating growth promoting antimicrobials (AGP), while the second scenario assessed impacts of eliminating both growth promoting and preventive antimicrobial (NoPrev) use.

2.4.4. No growth promoting antimicrobials

Williams et al. (1997) estimated 12.7% increase in the metabolic maintenance energy requirement (MMER) when pigs have poor health. To simulate elimination of AGP from the production in the nursery phase, the MMER in the NRC growth equations for pigs between 5 and 23 kg was increased by 12.7%. The grow-finish phase of the production was assumed to be unaffected by elimination of AGP, as far as pig performance is concerned.

The National Pork Board Taskforce suggested not using AGP could mean fewer pigs would reach the expected weight and size requirements in the production facility, which was estimated to increase voluntary cull rate in the nursery and grow-finish barn to 0.25% for median health facilities. Without AGP, the mortality rate was expected to increase by 0.2% in the nursery phase. Because AGP is used mostly in the nursery phase, production without use of AGP was expected to have no impact on mortality rates in grow-finish barn.

2.4.5. No growth promoting and preventive antimicrobials

In this scenario, the effects of production without use of either AGP or preventive antimicrobial use on performance parameters were estimated. When herd health is trending downward, antimicrobials are used prophylactically to reduce the chance of herd-wide infection. Animals which become sick are treated therapeutically and will recover or die. Without preventive use, more animals are likely to need therapeutic doses. Whittemore et al. (2001) reported that chronic diseases in pigs increase the maintenance energy requirements by up to 1.3 times the normal predicted value. However, in the current scenario it was assumed that not using preventive antimicrobials in the grow-finish barn does not necessarily mean the pigs fall sick. It was assumed that without AGP and preventive antimicrobials in the production, the performance of pigs would be poor compared to the baseline. Therefore, MMER of pigs in the nursery and grow-finish barns was increased by 12.7% (Williams et al. 1997) and 15% respectively.

Without AGP and preventive antimicrobial use in the production the voluntary cull rates and mortality was expected to increase by 4% in the nursery and 5 and 5.5% respectively in grow-finish barn.

2.4.6. Immunocastration

Surgical castration of male pigs without anesthesia within first 1 to 2 weeks of age is a standard industry practice (FAO , Thun et al. 2006). Besides preventing boar taint in the meat, which is a result of skatole levels higher than 0.2 μg g^{-1} of fat, surgical castration also improves meat quality and suppresses aggressive behavior in pigs (Dunshea et al. 2001, Morales et al. 2010, Thun et al. 2006). However, surgical castration is under scrutiny of animal welfare groups because the procedure is painful and distresses pigs (Millet et al. 2011, Morales et al. 2010).

An alternative to the surgical castration that is being studied is immunocastration, which involves administering male pigs a dose of gonadotropin-releasing hormone (GnRH) which creates antibodies against GnRH and reduce skatole production. Dunshea et al. (2001) reported that immunocastration also reduces size of testes in male pigs suppressing sexual aggressive behavior. This compound is administered at about 9 weeks of age and then again between 3 and 10 weeks prior to slaughter. Because male pigs perform like boars, which means they gain leaner muscle mass, until the second dose of GnRH compound, immunocastration offers improved ADG and FE in male pigs compared to surgically castrated pigs (Batorek et al. 2012).

The performance of immunocastrated (IC) pigs was modeled as a split sex barn with half males and half gilts. The NRC growth model for growing-finishing pigs assumes not effect of pig sex on the MMER (National Research Council 2012). However, it is assumed in the model that entire males have lower metabolizable energy intake (MEI) compared to the barrows.

Effects of immunocastration after second injection were captured in the model by increasing estimated MEI by 21% and reducing MMER and Pd by 12 and 8% respectively. No changes to the diet formulation were made for the immunocastration scenario.

2.4.7. Gestation stalls

Gestation stalls offer benefits such as maximum barn space utilization and controlled feeding, but the management practice has criticized by animal welfare groups because the stalls offer sow minimum or no free movement (Lammers et al. 2007). Group housing reduces the stocking density and thus requires additional housing to maintain animal production. Due to the difference in barn infrastructure necessary for the alternate management using gestation pens, the LCA scenarios have included the effect of changes in the infrastructure. A 10 year life for the barn facility, including the stalls and pens was assumed for this scenario. A bill of materials for construction of sow, nursery and grow-finish barns from plans published by Iowa State University Midwest Plan Service was created (data not published).

This scenario was designed to evaluate environmental impact of production management using gestation pens. Data for comparison between gestation stalls and group pen housing were obtained from published articles. This scenario evaluated the option of using gestation stalls for the entire gestation period only. It was assumed that farrowing stalls were used for both group pen and individual stall scenarios. The differences between sows housed in gestation stalls and in group pens were observed in number live births, litter size, pre-weaning mortality, and piglet weights at birth. An analysis of data obtained from peer-reviewed articles was performed to prepare scenarios for group and gestation housing (Table 2). These numbers were close to the results reported by (McGlone et al. 2004).

Bates et al., (2003) reported that 72% of sows housed in group returned to estrus within 7 days compared to 68.4% of sows in gestation stalls. In addition, 94.3% of group housed sows remained pregnant after initial service compared to 89.4% of sows in stalls. These differences were capture in the PPEF model by adjusting the average number of days between piglet weaning and insemination.

Table 2. Production parameters for gestation stalls and group housing

	Gestation stalls	**Group pens**
Litter size	10.5	10.34
No born alive	9.55	9.41
Preweaning mortality	15.4%	16.3%
Pigs weaned	8.08	7.88
Weight per piglet	1.5	1.53
Backfat thickness (mm)	19.6	20

Averages of data obtained from Anil et al. (2005), Bates et al. (2003), Harris et al. (2006), Lammers et al. (2007), SCHMIDT et al. (1985), Wang et al. (2011)

3. Results and discussion

Results of the LCA for the baseline and five pork production management strategies are presented in Analysis of the changes in environmental impact category metrics as a result of changed inventory from the PPEF for each management strategy showed that some strategies increased impacts, while others decreased impacts (Figure 1, 2 and 3). These analyses represent simulated estimates of impacts and should be interpreted as potential trends rather than absolute estimators.

3.1. Ractopamine

Not using ractopamine resulted in 6.5% increase in global warming potential, 4.6% increase in fossil fuel increase, and 5.6% increase in water use. The driving factor for the increase in GWP from removal of ractopamine was lowered productivity during the last month of finishing. The model simulations showed that days in the barn are increased when RAC is not used in the production. This directly affects the quantity of feed consumed, manure

produced, and requires a small increase in necessary barn infrastructure to support the same annual lean pork production (i.e., a decrease in the number of turns per barn per year).

3.2. Antimicrobials

Not using antimicrobials as a growth promoting strategy resulted in 1.6% increase in global warming potential, 1.8% increase in energy use, and 3% increase in water use. The increased GWP was driven by two factors: lowered daily gain and feed efficiency leading to increased feed consumption and time required to reach market weight, and thus additional manure production as well. If preventive use of antimicrobials is avoided, there will be additional mortality, as well as further decrease in daily gain and feed efficiency compounding the effect. Finally, additional barn infrastructure will be needed due to lengthened time to reach market weight.

Coupling removal of AGP with not using antimicrobials for disease prevention resulted in 17.4% increase in global warming potential, 18.6% increase in energy use, and 18.9% increase in water use, the largest changes in this assessment. The effects of not using antimicrobials for disease prevention were driven by the same process impacts as not using them for growth promotion, compounded by increased mortality across the entire herd.

3.3. Immunocastration

This management alternative resulted in 2.3% decrease in global warming potential, 2.5% decrease in energy use, and 1.9% decrease in water use. This alternative approach to controlling boar taint resulted in increased average daily gain and reduced daily feed intake compared to baseline. In the grow barn, using immunocastration also resulted in increased cycles per year. This resulted in less overall feed consumption and manure production as well as a small reduction in the necessary barn infrastructure associated with the faster average turn-around for the barns.

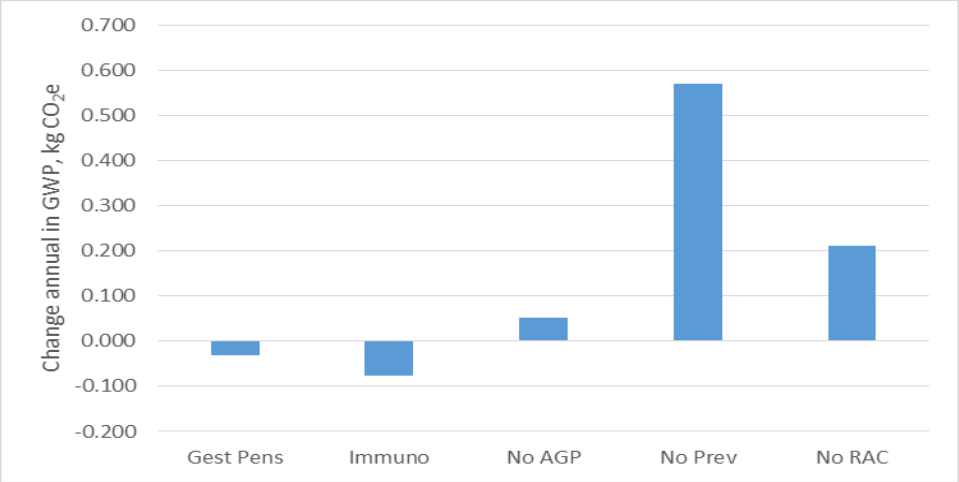

Figure 1. Estimated potential change in annual global warming potential (kg CO_2e) resulting from US production strategies for 1 kg live weight at farm gate

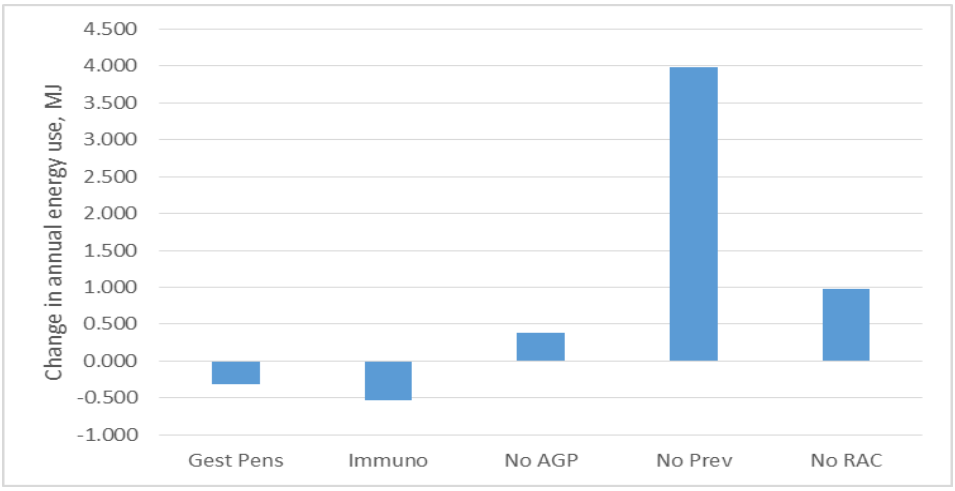

Figure 2. Estimated potential change in annual energy use (MJ) resulting from US production strategies for 1 kg live weight at farm gate

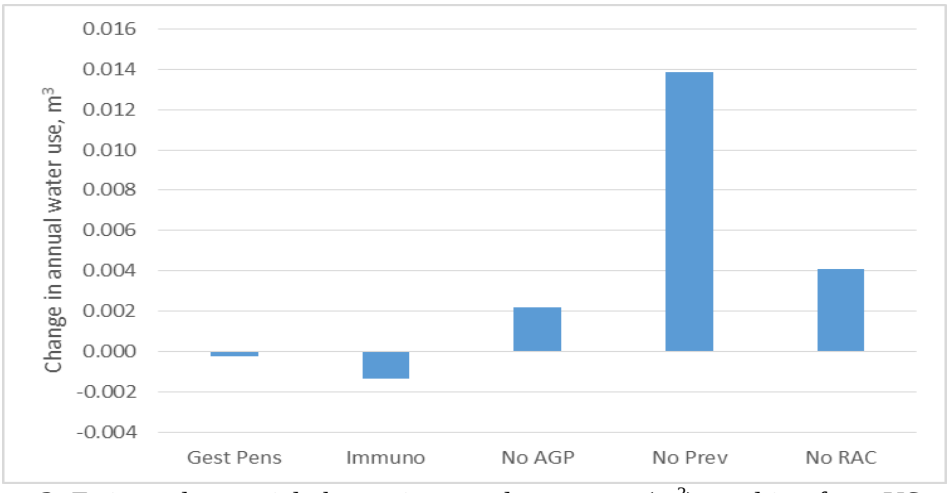

Figure 3. Estimated potential change in annual water use (m^3) resulting from US production strategies for 1 kg live weight at farm gate

3.4. Gestation pens

Using pen gestation structures rather than stall gestation structures resulted in 1% decrease in global warming potential, 1.5% decrease in energy use and 0.3% decrease in water use. Lower GWP observed in this scenario was a result of lower feed consumption and lower manure emissions. However, the barn infrastructure requirements for pens are 65% larger, based on our modeling of the space requirements for sow in stalls compared to pens. This increase the GWP, which is amortized over the expected life of the barn, and essentially offsets the lower GWP observed for this scenario. The lower energy demand appears to be a result of lower electricity use for fans observed for gestation pens.

4. Conclusion

Life cycle analyses of five pork production strategies for three environmental impact categories for yielded a range of results, from 17% increase in global warming potential (removing AGP and preventive antimicrobials) to approximately 2.5% reduction in energy use (immunocastration). Based on LCA results, the following pork production strategies increased environmental impact metrics across all three impact categories: not using antimicrobials for growth promotion or disease prevention and not using ractopamine for growth promotion. Conversely, using immunocastration and pen gestation production strategies decreased global warming potential

and energy use, and water use. The results of this study indicate that changes made to production practices in the swine industry, could affect sustainability metrics and therefore need cautious evaluation. These results however, are the product of simulation of pork production strategies combined with unit process LCAs; these models are very sensitive to time in the barn at each growth stage, temperature inside the barn, and mortality rates and therefore should be interpreted cautiously.

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