Improvest®

(Gonadotropin Releasing Factor Analog-Diphtheria Toxoid Conjugate, 0.2mg/mL)

THE ENVIRONMENTAL BENEFITS

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Introduction

AUTHORS

Garth Boyd, Ph.D., PAS, The Prasino Group • Greg Thoma, Ph.D., University of Arkansas
Marty Matlock, Ph.D., University of Arkansas • Gian Luca Baldo, Ph.D., Life Cycle Engineering

As the world's population continues to grow, global meat consumption will also increase. Therefore, there is pressure from all sectors of society to produce food more sustainably. The demand for more meat must be met by using fewer resources while simultaneously mitigating the environmental burdens associated with agricultural production. This will mean further intensification and industrialization of livestock production and adoption of technology that improves production efficiencies while also accounting for animal welfare issues.

Improvest® (*gonadotropin releasing factor analog-diphtheria toxoid conjugate*) is an FDA-approved veterinary prescription product to manage unpleasant aromas that can occur when cooking pork from some male pigs. It is a protein compound that works like an immunization to temporarily protect against off odors in pork. Its related global brand, Improvac®, has been used successfully by farmers in other countries for more than 10 years. Male pigs are given Improvest in the finish phase to manage odors scientifically known as boar taint, eliminating the need for physical castration early in life. As a result they are able to grow to their full, natural potential, with all inherent advantages of the intact male until the second dose is administered. The FDA has determined that pork from pigs given Improvest is safe to eat and there are no residues that could affect human health. Regulatory authorities in more than 60 countries, including the European Union, Japan, South Korea, Russia, and China have reached the same conclusion.

The objective of the following study was to identify and quantify through life cycle assessment (LCA), the potential environmental benefits of using Improvest in US pork production. As defined by the International Organization for Standardization (ISO), a life cycle assessment is a "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 14040:2006). In this collaborative study between the Prasino Group, University of Arkansas Center for Agricultural and Rural Sustainability (CARS), and Life Cycle Engineering (LCE), environmental benefits were quantified by comparing the life cycle of Improvest managed pigs, also known as immunologically castrated barrows, to that of physically castrated (PC) pigs (PC barrows, the baseline scenario) using SimaPro – an LCA modeling program. Specifically, the study looked at four environmental metrics – greenhouse gas emissions, direct land use, water use, and nutrient use efficiency. The scope of this study was field to farm gate, and the functional unit was one pound of live weight or dressed carcass at the farm gate.

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Project Approach

Table 1. Environmental Impact Categories Used to Evaluate Pork Production Management Strategies

Environmental Impact Category	Unit	Description
Global Warming Potential (GWP)	kg CO2e	Greenhouse gas emissions based on IPCC GWP 100a
Cumulative Energy Demand	Btu	Non-renewable fossil fuel consumed by process
Water Use	gallons	Total volume of water consumed by process
Land Use	acre	Total area of land required to produce a designated mass of feed

The approach used for evaluating the impacts of Improvest on environmental indicators (Table 1) from pork production was to simulate swine production using lifecycle inventory inputs for unit processes constructed in SimaPro (Pre' Consultants, The Netherlands). Life Cycle Engineering has previously conducted an in-depth, global analysis of the environmental effects of substituting Improvest for physical castration. For this white paper, the growth and feed conversion performance of pigs, resource consumption, and emissions to the environment – specific to US production conditions – were incorporated into the LCE model to provide an analysis of the potential benefits of adopting Improvest in the US swine industry. These modifications were based on data published in peer-reviewed literature, government reports, and information from Zoetis (Morales et al., 2012; Morales et al., 2010; Thoma et al, 2011; Pfizer, 2011; USDA-NASS, 2012). Based upon these data sources, improved feed conversion from Improvest use is expected to result in an 8.4% reduction (Cowles et al., 2013) in the ration necessary to reach a market weight of 275 pounds (in comparison to conventional production). There is a cascading effect of this improved conversion: fewer resources are necessary to produce the ration and less manure is produced. Other US-specific adaptations made for this white paper include updating the typical US swine ration to include dry distiller's grains solubles (DDGS), replacing global grain production with US-specific production (corn and soybeans), and including the effect of yield (USDA, 2011). An inclusion rate of approximately 12% was assumed for DDGS. The final adjustment to the input parameters was an updated profile of manure management practices common to US production systems.

Projected impacts of Improvest versus conventional physical castration in US pork production were calculated based on the reduced feed and manure necessary to produce a pound of live weight or dressed carcass at the farm gate. The land use impact was based on average US yields of corn and soybeans. Specifically, in the case of soybean meal, a 73 percent yield was used (i.e. 73 lbs of soybean meal per 100 lbs of beans); and a 57 percent economic allocation for soybean meal versus oil at the mill. In the case of corn a 100 percent yield was used; however, DDGS were only assigned a portion of the corn production burden since 98 percent of the impacts associated with corn used for ethanol production are allocated to the ethanol. This leaves only two percent of the footprint to reside with the DDGS. This GHG accounting procedure is widely accepted and is known as economic allocation of the GHG burden meaning that the revenue from corn production was primarily for the production and sale of ethanol. Water use was similarly allocated based on crop water use. Irrigation water demand (water consumption only – also known as 'blue' water) per pound of crop produced was determined using the USDA-NASS dataset in SimaPro (Thoma et al., 2011). Water savings were calculated on the basis of the feed rations saved through Improvest adoption. Energy requirements to produce each crop were also determined using SimaPro and the savings similarly calculated based on the feed rations saved.

Projected impacts of Improvest versus conventional physical castration in US pork production were calculated based on the reduced feed and manure necessary to produce a pound of lean pork at the farm gate.

RESULTS AND DISCUSSION

Results of the LCA for the baseline and Improvest pork production management strategies are presented in Tables 2 through 8. Over the production cycle of pork, Improvest managed pigs consume on average 8.4% less feed than PC pigs (Table 2). The improvement in feed efficiency resulting from using Improvest also reduced manure production by 22 gallons per Improvest managed pig. Based on an average pig live weight at harvest of 275 pounds, using Improvest could reduce greenhouse gas emissions by as much as 63 lbs of CO_2 equivalents per pig (0.25 lbs CO_2 equivalent/lb live wt x 275 lbs live wt; Tables 3 and 4). Improvest managed pigs had a 6.1% and 3.8% improvement (decrease) in CO_2 equivalent/lb live weight and carcass weight, respectively, for greenhouse gas emissions compared to PC pigs (Table 3, US Average figures). Carcass weight for physically castrated barrows

Table 2. Feed Consumption (lbs/pig) for Production of Physically Castrated and Improvest Managed Pigs in the US

Feed Component	Physical Castration (lbs/pig)	Improvest managed (lbs/pig)
Corn	446.2	408.7
DDGS	82.1	75.2
Soybean meal	135.5	124.1
Fat	13.5	12.3
Dried whey	2.7	2.5
Supplement	7.6	6.9
Dical-limestone	11.2	10.3
Blood meal	0.7	0.7
TOTAL FEED	**699.5**	**640.7**

Table 3. US Farm Gate GHG Emissions (lbs CO_2 equivalent) as a Function of Manure Management Technology and US Weighted Average for Physically Castrated and Improvest Managed Pigs

Manure Management Strategy	Physically Castrated Pigs		Improvest Managed Pigs	
	lbs CO_2 eq. per lb of live weight	lbs CO_2 eq. per lb of dressed carcass	lbs CO_2 eq. per lb of live weight	lbs CO_2 eq. per lb of dressed carcass
Anaerobic Lagoon	4.87	6.49	4.56	6.22
Deep Pit	3.54	4.72	3.32	4.54
Solid Storage	2.46	3.29	2.32	3.17
US Average	3.71	4.95	3.48	4.76
Global Average	–	–	5.10	6.70

Table 4. Pig Manure Component Amounts for Physically Castrated and Improvest Managed Pigs

Manure Composition	Physical Castration (lbs/pig)	Improvest Managed (lbs/pig)
Volatile Solids	108.0	98.9
Nitrogen	11.2	10.3
Phosphorous	1.8	1.7
Potassium	4.9	4.4

was based on an industry carcass yield of 75% for a 275 lb at harvest (Thoma et al., 2011) and, for Improvest managed pigs, the carcass yield was 1.75% lower (73.25%, Cowles et al.,) 2013) for a 275 lb hog.

An analysis of the global warming potential across all categories of production showed that feed production and manure management account for 71% of the total greenhouse gas emissions from US pork production (Figure 1). Reducing impacts from these significant contributors would have a dramatic impact on greenhouse gas emissions.

Based on 2011 average US corn and soybean yields, feed savings resulting from Improvest use could reduce

Figure 1. Global Warming Potential by Production Category for US Pork

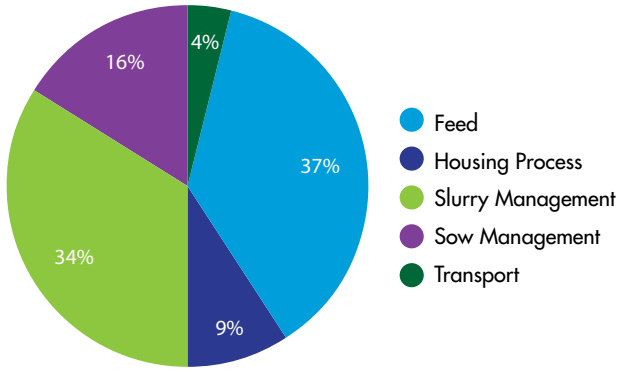

Table 5. US Pork Production Greenhouse Gas Emissions Reduction Associated with Manure Management for Improvest Managed Pigs

Manure Emission Reductions (lbs/pig)	Anaerobic Lagoon	Deep Pit	Pasture/Solid Storage	Total
Management Adoption (% by head, 2007)	31.9	62.9	5.2	100
CH_4	2.2	1.1	0.1	3.4
N_2O	0.0	0.002	0.007	0.009

Table 6. Land Area and Water Saved by Feed Reduction from using Improvest

Feed Component	Feed Saved (lbs/pig)	Yield (lbs/acre)	Land Saved (acres/pig)	Water Saved (Irrigation, gal/pig)
Corn + DDGs	37.6[1]	8775.5	0.0043	35
Soybean Meal	11.4	2608.7	0.0034[2]	95

[1] Does not sum to the difference in Table 2 because 98% of corn production for DDGS is assigned to ethanol.

[2] Does not arise from division of saved feed and yield directly because soybean meal is assigned only a fraction of the soybean production (remainder assigned to soy oil and hulls).

If two thirds of US pork producers adopted Improvest for reduction of boar taint, US pork producers would reduce their greenhouse gas emissions by just over a million metric tonnes of CO_2 equivalents, save more than a million tons of feed, and reduce land use demand by over 270,000 acres.

Table 7. Potential Reduction across Impact Categories for Three Levels of Adoption of Improvest in US Pork Production

	Improvest Adoption Rate		
	33%	**66%**	**100%**
CO_2 equivalent Emissions Reductions (million kg CO_2e)	507	1,014	1,523
Feed Use Reductions (tons)	522,000	1,044,000	1,567,000
Energy Use Reduction (million BTU)	1,850	3,700	5,550
Water Use Reduction (billion Gallons)	2.3	4.6	6.9
Land Use Reductions (acres)	137,000	274,000	411,000

the amount of land required for feed by 0.0077 acres/pig (336 ft^2). Furthermore, this reduction in land use could result in 110 MJ (~104,000 BTU) reduction in energy use and a 130 gallon/pig decrease in water use (Table 6). In 2011, the US pork industry produced 53,300,150 barrows (USDA, 2011).

The potential environmental benefits of using Improvest in US pork production are a function of adoption rate (Table 7). If two thirds of US pork producers adopted Improvest for reduction of boar taint, US pork producers would reduce their greenhouse gas emissions by just over a million metric tonnes of CO_2 equivalents, save more than a million tons of feed, and reduce land use demand by over 274,000 acres (Table 7). Full adoption of Improvest could save the US Pork Industry almost 6 PJ (5,550 billion BTUs) of energy and 6.9 billion gallons of water per year (Table 7). The improved feed efficiency, weight gain and carcass composition of intact males treated with Improvest compared to barrows drives these efficiencies.

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AUTHORS

Gian Luca Baldo is an engineer with a Ph.D. and a Post-Doc in "sustainability assessment of production processes" and "Life Cycle Assessment (LCA)" at Polytechnical University of Turin, Italy.

After the academic experience, he worked several years as professional independent engineer for an English company (Boustead Consulting Ltd.) and gained experience in environmental audits to support the sustainability assessment tools development for environmental strategy definition, implementation and communication of multinational companies, manufacturer and business associations at international level.

In the late nineties, he founded Life Cycle Engineering (www.studiolce.it) an environmental boutique to offer qualified consultancy in the environmental sustainability area.

Garth Boyd, Ph.D., PAS is a senior partner of the Prasino Group. He works with agribusiness companies and government agencies on renewable energy and sustainability issues.

Garth has worked in various aspects of agriculture for the last 35 years, first as a ranch hand, then ranch manager during and after obtaining a BSA from the University of Georgia. After graduate degrees at the University of Georgia (MSA) and Kansas State University (Ph.D.), he began his academic career as an assistant professor on the Animal Science's faculty at Colorado State University where he was the Extension Beef Specialist for seven years. Garth then joined industry as a leader – for Murphy Farms in North Carolina where as director of environmental affairs, he led that company into the era of environmental stewardship, for Smithfield Foods as director of environmental technology and for Camco, a global carbon firm, as Senior Vice-President of Agricultural Services

Garth was a two-term member of the USDA Agriculture Air Quality Task Force and NC Pork Council Board. He was appointed by the EPA Administrator in 2007 to the inaugural EPA Farm, Ranch and Rural Communities Advisory Committee. In 2008, Garth was inducted into the Farm Foundation Members Round Table.

Dr. Marty Matlock, Ph.D., P.E., B.C.E.E. is a professor of ecological engineering in the Department of Biological and Agricultural Engineering at the University of Arkansas. Dr. Matlock is a registered professional engineer and a board certified environmental engineer in sustainable design. He serves as the Executive Director of the UA Office for Sustainability and Area Director for the Center for Agricultural and Rural Sustainability. Dr. Matlock's research focus is on the impact of human activities on ecosystem dynamics at the watershed scale. He teaches courses in ecological and environmental risk assessment, life cycle assessment, and sustainable systems design. Dr. Matlock serves on six international and national committees for sustainable agriculture, advises 11 international companies on sustainability strategies, and serves as the chair of the Cherokee Nation Environmental Protection Committee.

Greg Thoma, Ph.D. served as director for research and is currently senior advisor to The Sustainability Consortium, a joint effort of the University of Arkansas and Arizona State University. He has represented the Sustainability Consortium on the United Nations Environment Program/Society of Environmental Toxicology and Chemistry Lifecycle Initiative board of directors assisting in coordination of international efforts to mainstream life cycle management in the consumer goods sector. He has been on the faculty at the University of Arkansas since receiving his Ph.D. in Chemical Engineering in 1994 from Louisiana State University, and is a Registered Professional Engineer in the state of Arkansas.

Dr. Thoma's research focuses on the application of chemical engineering principles to find solutions to environmental problems. He is currently lead investigator for a number of life cycle initiatives in the food and agriculture sector including studies on fluid milk, cheese, milk delivery systems, and is project director for a 5-year, $5M USDA multi-university project focused on greenhouse gas mitigation for US swine production. Recently he became the scientific lead for the UNFAO Partnership on the Environmental Benchmarking of Livestock Supply Chains technical advisory group for poultry which is working to create guidance in the application of LCA for assessment of sustainable poultry and egg production.

QUESTIONS & ANSWERS

The questions in this section were not derived from the authors, but were questions asked of Zoetis and answered by Zoetis.

Q How does immunological castration of pigs (use of Improvest) benefit the environment?

A Male pigs on an Improvest program grow to their full potential with all the inherent advantages of intact males until the second dose. They convert feed to pork more efficiently, meaning they eat less feed and produce less waste, while creating more pork.

Q What is an Environmental Product Declaration (EPD) and who issued the Improvest EPD?

A An EPD is an ISO standardized way of quantifying the environmental impact of the production and use of a product. Declarations include information on:

- The environmental impact of raw material acquisition;
- Energy use and efficiency;
- Content of materials and chemical substances; and
- Emissions to air, soil and water and waste generation.

Q How can the Improvest EPD be used?

A Improvest EPD enables stakeholders in the U.S. pork supply chain to base their corporate social responsibility claims on data substantiated through the stringent EPD process.

Q What is the difference between the Improvest EPD and the U.S. Lifecycle Assessment (LCA)?

A The Improvest EPD is based on a global LCA with pork production data from numerous countries comparing Improvest-managed hogs to physically castrated hogs. The primary purpose of an EPD is to communicate relevant environmental information about a product or systems value chain. The information found in an EPD comes from a LCA conducted in accordance with the appropriate ISO standard. The global LCA was used to build an EPD.

The U.S. LCA used US-specific data and is stand alone with regards to results.

Q Why does the Improvest EPD show a 3.7% improvement in feed conversion while the U.S. LCA shows an 8.4% improvement?

A The Improvest EPD included information gathered from 12 countries including Australia, Brazil, Canada, Chile, China, France, Japan, Mexico, Netherlands, Spain, United Kingdom and The United States of America. The U.S. LCA only used U.S.-specific data. The data comparison of trials from U.S. farms comparing Improvest managed market hogs to those physically castrated demonstrated a significantly greater improvement than the average of the 11 other countries. Some of this difference is because the US trials were done later and incorporated new knowledge about how to best feed and rear Improvest managed pigs to maximize their productive potential.

Q What happens to residues of Improvest excreted in the urine and feces of pigs?

A Proteins like Improvest are broken down in the body of the pig and are ultimately used as nutrients, either providing energy or building blocks for animal growth. The EU European Medicines Agency and US Food and Drug Administration's Center for Veterinary Medicine

concluded that no the product or the protein metabolites that are excreted will pose any risk to aquatic and terrestrial ecosystems.

Q How were the water savings in the LCA calculated?

A The team of independent professionals referenced public data regarding irrigation of crops and calculated the impact on water related to feed savings in the LCA.

Q Why is the reduced environmental footprint on pork production important to consumers?

A The growing global demand for animal protein requires all of us to do more with less. Zoetis recognizes the importance of Improvest enabling producers, processors and retailers to be socially responsible, environmentally sound and economically viable. At the same time, the adoption of Improvest in the U.S. alone will save the equivalent of the following resources:

- 2 times the area of land encompassed by the five boroughs of New York City.
- Land area equivalent to over 300,000 football fields.
- Area equivalent to over 2500 quarter sections or 630 sections of land.
- Enough feed to fill over 700 million cereal boxes.
- Enough water to meet the needs of 39 million Americans for one day.
- Enough water to fill over 10,000 Olympic size swimming pools.
- Eliminating the annual GHG emissions from over 380,000 cars.

Q How did Zoetis calculate the environmental benefits of Improvest for U.S. pork production?

A A team of independent, internationally respected professionals including: Gian Luca Baldo Ph.D., Life Cycle Engineering, Garth Boyd, PhD, The Prasino Group, Marty Matlock, PhD, and Greg Thoma, PhD, University of Arkansas, ran life cycle burden data such as cultivation yield for feed grains, ration composition and manure management from U.S. pig farms through an ISO compliant lifecycle assessment. Their work compared the environmental footprint of Improvest-managed market hogs to physically castrated market hogs.

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