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National scan-level carbon footprint study for production of US swine

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Abstract

The National Pork Board commissioned the University of Arkansas' Applied Sustainability Center to conduct a life cycle assessment (LCA) of the US pork supply chain, with primary focus on defining greenhouse gas (GHG) emissions. GHG emissions are commonly defined in terms of the cumulative global warming potential (GWP) of all greenhouse gases emitted for a system or product, and in this case across the supply chain necessary to provide pork products to the consumer. The GHG of primary concern are carbon dioxide (CO2); methane (CH4); nitrous oxide (N2O); and common refrigerants. The GWP for a system is reported in terms of carbon dioxide equivalents (CO2e) derived by converting non-CO2 gas emissions to an equivalent 'global warming potential' quantity of CO2. The analysis was carried out for the functional unit of the consumption of one serving (4 ounces) of boneless pork. The system study boundaries encompassed feed production; swine production; delivery to processor; processing; packaging; distribution; retail; and consumption/disposal. The primary time frame for the study was 2009.

The production system considered activities performed in support of pork production and delivery, extending to GHG burdens of raw material extraction such as fertilizer production, primary fuel extraction, delivery, combustion and, for electricity, transmission and distribution losses. The system specifically included production of polystyrene and other packaging material. Also, the impacts of distribution and refrigeration, as well as product loss through the supply chain, were included.

Raw data were provided from industry experts and standard swine industry handbooks. Regionally specific data for feed crops were taken from farm extension and the National Agricultural Statistical Service regarding the energy and GHG emissions associated with production. Additional input data for fuels and electricity consumption for crop production were obtained from the technical literature, state agricultural extension services, the US Department of Energy, the USDA, and other academic institutions. GHG emissions from manure were calculated, based on IPCC recommendations,[1] from ASABE manure management guidelines[2] and from the Purdue Pork Industry Handbook. Transport emissions from producer to processor and from processor to distributor were calculated from information provided from industrial sources. And, cradle-to-grave contributions from packaging included production of raw materials (polystyrene, shrink wrap, paper etc.) and ultimate disposal of the materials.

This paper summarizes a scan level carbon footprint analysis for a single serving of pork prepared for consumption through evaluation of GHG emissions across the entire production and delivery system with relatively low resolution and high data aggregation – that is, it is not for a specific production system, but represents an overall average of US production, processing, and distribution systems. The available life cycle data, by production stage, and the methodology for calculation of the carbon footprint are described. It was found that the major impacts of swine production occur in crop production, manure management, and retail distribution and consumption. The overall estimated average carbon footprint for preparation and consumption of one 4 ounce serving was 2.2 lb CO2e with a 95% confidence band from 1.8 lb CO2e to 2.7 lb CO2e. The contribution of emission burden for each stage was found to be approximately:

a. 12% from breeding and lactating sows(including feed and manure handling);
b. 60% from nursery to finish (including feed and manure handling);
c. 5.3% from processing and packaging;
d. 9.4% from retail (electricity and refrigerants); and
e. 3.3% from the consumer.

Introduction

The pork supply chain is broadly divided into 8 stages; each receiving a separate analysis that was combined to provide the entire life cycle footprint. These stages are: feed production; live swine production; delivery to processor; processing; packaging; distribution; retail; and consumption/disposal. Analysis of the pork supply chain can be used to provide the insight necessary to identify critical leverage points where, in turn, innovation can lead to increased efficiency in the supply chain while simultaneously leading to reductions in the carbon footprint of pork products. This project has been conducted in compliance with ISO 14040:2006 and 14044:2006 standards for life cycle assessment. It should be noted that a full LCA should also evaluate impact metrics that include other effects such as human health impact, ecosystem quality, and resource depletion.

2.1: Goal and scope definition

Determine GHG emissions associated with delivery, preparation, and consumption of one serving of pork to US consumer. Because of the strong link between energy consumption and greenhouse gas emissions, it is frequently the case that high greenhouse gas emissions are indicative of opportunities for improved energy efficiencies or conservation.

2.1.1: Project scope and system boundaries

This life cycle assessment was a cradle-to-grave analysis of the carbon footprint or global warming potential of the production and consumption of boneless pork. The system boundaries encompassed effects beginning with the energy and greenhouse gas (GHG) emissions associated with production of fertilizer, and with estimates of greenhouse gas emissions from either landfill or municipal waste incineration of the packaging. Incidental effects such as employee's commutes, nor the cost of heating the farmer's residence have not been included. Nor does the scope of this project extend to other potential environmental effects such as nutrient runoff, topsoil loss, or depletion of freshwater supplies; it focused on evaluation, at the national scale, of the global warming potential attributable to production and consumption of pork in the United States. The primary time frame for the study is 2009.

2.1.2: Functional unit

The functional unit of this study was one 4 ounce serving of boneless pork prepared for consumption by a US consumer.

2.1.3: Life cycle impact assessment

For this project a single impact assessment metric as been chosen, global warming potential. We have adopted the most recent IPCC recommended GWP100 equivalencies for this project (Forster et al., 2006): CO2 = 1; CH4 = 25; and N2O = 298. Global warming potential equivalents are also presented for most common refrigerants in this document.

2.2: Life cycle inventories

Published literature is used as the basis for much of the life cycle inventory data, and additional discussions with industry representatives and other experts helped fill in the data gaps. The production system encompassed activities performed in support of pork production and delivery extending to GHG burdens of raw material extraction for fertilizer production, primary fuel extraction, delivery, combustion and, for electricity, transmission and distribution losses. The system included production of polystyrene foam shells, shrink wrap, and adsorbent pads used to package meats in supermarkets.

2.2.1: Conceptual farm production model

To simplify mass and energy accounting we have chosen not to use a barn or batch of weaned piglets as the computational basis, instead the computational farm model is based on the productive life of one sow. The average number of litters (parities) and the number of piglets per litter are used to determine the total feed and on-farm energy requirements. The cumulative and GWP impacts from all the inputs are divided by the total mass of the finished animals produced by that sow.

2.2.2: Crop production

In consultation with industry experts, we have identified the most common feeds and have collected available information from farm extension and the National Agricultural Statistical Service regarding the energy and greenhouse gas emissions associated with production of these crops.

Our initial analysis defined dry distiller grains (DDGs), a byproduct of corn ethanol production, as an important contributor to GWP of the feed. Assuming 9.5 piglets per litter, the total quantity of each feed component consumed by all the animals passing through the system over the course of 3.5 litters (on average) for a sow was calculated. In essence, this is an integration of all of the feed crossing the farm gate resulting in the production of 30 finished pigs plus one sow. The total quantity of each feed component was multiplied by the carbon footprint for the production of that feed to give the overall feed footprint.

2.2.3: On-farm manure management

Different manure management systems result in different quantities of greenhouse gases, primarily methane and nitrous oxide, emitted to the atmosphere. The IPCC provides guidance on estimating the quantities of greenhouse gases which are emitted as a function of the specific management system. We have used the American Society of Agriculture Engineers (ASAE, 2005) recommendations to predict the quantity of manure generated, as well as to estimate the amount of nitrogen excreted in the manure. Manure management systems included in the model are deep pit and anaerobic lagoons.

2.2.3.1: Methane and nitrous oxide emission due to manure management

We employed standardized methodologies as laid out in the IPCC 2006 guidelines in estimating the annual CH4 and N2O emission factor (EFT) from manure (Dong et al., 2006). We have used the ASABE guidelines to define the average manure characteristics, in particular the volatile solids content which is significant in determining the quantity of methane that can be produced under anaerobic conditions. US monthly average temperature data were extracted from the National Climatic Data Center.

2.2.4: Farm to processor transportation

Interviews with industry experts provided insight into the structure and characterization of transportation from farm to processor. We used an estimate of 500 miles transportation distance between the farm and the pork processor. These calculations are based on an estimate of 160 head with an average weight of 268 pounds per truck for delivery of finished hogs. This estimate will be further explored and developed as the study progresses.

2.3: Pork processing and packaging

Data were obtained from industrial sources, and aggregated to preserve anonymity for those who supplied data. We received data from over 10 meat processing facilities. The information included the quantity of processed meat leaving the facility, the amount of electricity, natural gas, and other fuels consumed for the entire facility. Estimates of greenhouse gas emissions from onsite waste water treatment facilities, and loss of refrigerants were also reported. Industrial GHG reporting is typically based on finished product leaving the facility and does not specifically account for rendering products; however, in life cycle assessment, when a system has multiple products, each of which have economic value, it is standard practice to assign some of the environmental impact burden from that process to each of the co-products. An economic allocation among the co-products is often the most practical approach to this allocation of environmental burden. One approach to arrive at an economic allocation is to consider data from the US economic census. The allocation ratio calculated using this method assigns 89% of the greenhouse gas burden to the meat processing and 11% assigned to the products from rendering operations.

2.3.1: Uncertainty

Monte Carlo simulation was used to address uncertainty and ranges of emission factor data and input information. When provided, we used the probability density functions for unit processes available in the EcoInvent, or other databases. For unit processes which were created for this project, the reported variation, or calculated variability, in conjunction with an assessment of the data quality followed the EcoInvent hierarchy.

2.4: Retail

After distribution from the processor to the retail gate, pork is displayed for consumer purchase. During this phase, there are four distinct emissions streams: refrigerant leakage, refrigeration electricity, overhead electricity and overhead fuel. Estimates of the sales volume, space occupancy, and energy demands of pork were used to determine the burden of this supply chain stage. Overhead electricity demand activities allocated to pork include ventilation, lighting, cooling, space heating, water heating, and other miscellaneous electrical loads (e.g., free standing refrigerators).

2.5: Consumer

Impacts accounted in this phase include transport from retail to home, refrigeration energy, and cooking energy. Estimates of the consumer cooking energy for gas and electric ovens were made. Cooking energy requirements were estimated using information from the US EPA Energy Star program. Both pre-heat and cooking times were included, but assumed no additional idle time. Also assumed was that the cooking energy was based on cooking eight 4-ounce servings (e.g., as a 2 pound tenderloin to be cut into individual servings and cooked).

2.6: Post-consumer solid waste

There's a relatively small quantity of postconsumer waste generated, and it is modeled using an EcoInvent process for landfill disposal.

Results and discussion

The model for the footprint is based on a 2 barn system: Breeding/Gestation/Lactation barn (or Sow Barn) followed by a Nursery/Finish (N/F) barn. We recognize that this is not representative of all configurations; however, addition of a third Nursery barn and changing the N/F barn to a Grow/Finish barn will have relatively small impact in terms of a high level scan. Transportation between the nursery and grow-finish barns will be the major additional in this case. The model is built to account for an entire life cycle of a single sow, and specifically includes gilt development and multiple litters (parities). The N/F barn accounts for all the piglets from all parities grown to full weight. Each unit process, or stage, has inputs and outputs that contribute to calculation of the overall GWP of the system.

The cradle-to-farm gate carbon footprint from this scan level study is within the same range as similar studies performed on European swine production systems which range from 3 to 5 kg CO2e per kilogram of dressed carcass. For the deep pit manure management system, the live production burden per kg of boneless meat is approximately 4 kg CO2e (the sum of Sow and Finish Barn contribution); which on a dressed carcass basis is approximately 2.7 kg CO2e (decrease by a factor of 0.65, the boneless fraction of a dressed carcass).

One somewhat surprising result of this analysis is that the contribution at processing and packaging is relatively low and that retail refrigeration and in home cooking are rather significant contributors to the overall carbon footprint.

We performed additional sensitivity tests for a 10 percent increase in the average number of litters from the herd as well as a 10% increase in the number of piglets per litter, and found that there was not a significant change in the carbon footprint. We also evaluated the difference between the diets with and without DDGs and, again, found that there is not a significant difference in the footprint.

The mean value, for a deep pit manure management system, is 7.5 kg CO2e per kg pork consumed. The mean value for an anaerobic lagoon system was 10.8 kg CO2e/kg boneless meat consumed.

Conclusion

In conclusion, the results of this scan analysis suggest that the mean value for cradle to farm gate production of pork in the US is within the range reported in the literature for pork produced elsewhere in the world. The results also show that both retail and in-home electricity use for refrigeration are non-trivial contributions to the overall footprint, while processing/packaging contributes a relatively smaller amount. Based on IPCC recommended calculations, the deep pit system is preferred to anaerobic lagoons due to reduced methane production.

The issue of allocation of burdens for feeds is an important one regarding reporting of carbon footprints, and it is recommended that a standard approach for handling agricultural byproducts like soybean meal and DDGS be agreed upon across the industries involved.

Finally, the choice of manure management system is crucial in determining the carbon footprint. The contribution of on-farm energy consumption represents about 25% of the farm contribution for deep pit systems and only about 10% for anaerobic lagoon systems. The resolution of this scan does not allow us to highlight clear energy saving opportunities; however, this will be one focus of the more detailed evaluation of live swine operations in the future.

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