
Abbreviations

AEZ	Agro-ecological zone
BFM	Bone-free meat
Bo	Manure maximum methane producing capacity
CV	Coefficient of variation
CH₄	Methane
CO₂-eq	Carbon dioxide equivalent
CW	Carcass weight
DE	Digestible energy
DM	Dry matter
DOM	Dead organic matter
EF	Emission factor
EI	Emissions intensity
FCR	Feed conversion ratio
GE	Gross energy
GHG	Greenhouse gas
GIS	Geographic Information System
GLEAM	Global Livestock Environmental Assessment Model
GPP	Gross primary production
GWP	Global warming potential
HFCs	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LAC	Latin America and the Caribbean
kWh	Kilowatt hour
LCA	Life cycle assessment
LPS	Livestock production system
LUC	Land-use change
LULUCF	Land use, land-use change and forestry
LW	Live weight
MCF	Methane conversion factor
ME	Metabolizable energy
MMS	Manure management system
NENA	Near East and North Africa
NIR	National inventory report
N₂O	Nitrous oxide
N_x	Nitrogen excreted
OECD	Organisation for Economic Co-operation and Development
SD	Standard deviation
SOC	Soil organic carbon
SSA	Sub-Saharan Africa
UNFCCC	United Nations Framework Convention for Climate Change
VS	Volatile solid
VS_x	Volatile solids excreted
Y_m	Percent of gross energy intake converted to methane

Definitions of commonly used terms

Anaerobic	In the absence of oxygen, i.e. conditions conducive to the conversion of organic carbon into methane (CH ₄) rather than carbon dioxide (CO ₂).
Breeding overhead	Animals that are kept to maintain the herd/flock size, rather than for production purpose.
Broiler	Chicken reared for meat.
By-product	Material produced during the processing (including slaughtering) of a crop or livestock product that is not the primary objective of production (e.g. meals and brans, offal or skins).
Carbon footprint	The total amount of GHG emissions associated with a product, along its supply chain, and sometimes includes emissions from consumption, end-of-life recovery and disposal. Usually expressed in kg or tonnes of carbon dioxide equivalent (CO ₂ -eq.).
CO₂-equivalent emission	The amount of CO ₂ emissions that would cause the same time integrated radiative forcing, over a given time horizon, as an emitted amount of a mixture of GHGs. It is obtained by multiplying the emission of a GHG by its Global Warming Potential (GWP) for the given time horizon. The CO ₂ equivalent emission is a standard metric for comparing emissions of different GHGs (IPCC, 4 AR 2007).
Coefficient of variation (CV)	The standard deviation (SD) expressed as a percent of the mean.
Cohort	Class of animals within a herd/flock defined by their age and sex (e.g. adult females, replacement females, males for fattening).
Co-product	Material generated by a production activity that generates more than one output (e.g. meat, eggs and manure are co-products of chicken production).
Crop residue	Materials left in an agricultural field after the crop has been harvested (e.g. straw or stover).

Direct energy	Energy used on-farm for livestock production, e.g. for lighting, heating and cooling.
Indirect or embedded energy	Energy used during the manufacture of farm inputs such as fertilizer or steel.
Emission factor (EF)	Factor that defines the rate at which a greenhouse gas is emitted, e.g. kg CH ₄ /animal/year or kg N ₂ O-N/kg manure N.
Emissions intensity (EI)	Mass of emissions per unit of product, e.g. kg CO ₂ -eq/kg of egg.
Feed conversion ratio	Measure of the efficiency with which an animal converts feed into tissue, usually expressed in terms of kg of feed per kg of output (e.g. LW, eggs or protein).
Feed material	Individual feed ingredient (e.g. grain or wheat straw).
Fieldwork	General term for the field operations undertaken during crop cultivation, e.g. ploughing, drilling, spreading.
Geographical Information System	A computerized system organizing data sets through the geographical referencing of all data included in its collections.
Global warming potential	Defined by the Intergovernmental Panel on Climate Change (IPCC), as an indicator that reflects the relative effect of a GHG in terms of climate change considering a fixed time period, such as 100 years, compared to the same mass of carbon dioxide.
Layer	Chicken kept to produce eggs for human consumption.
Manure N	Nitrogen in liquid and solid manure .
Methane conversion factor (MCF)	The percentage of the manure's maximum methane producing capacity (Bo) that is achieved during manure management (IPCC, 2006).
Monte Carlo analysis	Method that uses repeated random sampling for estimating uncertainty in results.

Pixel	The smallest unit of information in GIS raster data, usually square in shape. In GIS dataset, each pixel represents a portion of the earth, and usually has an attribute value associated with it, such as soil type or vegetation class. Pixel is often used synonymously with cell.
Ration	The combination of feed materials constituting the animal's diet.
Scavenging	Backyard animals roaming freely in search of ad hoc feed sources, e.g. food scraps, insects.
Second grade crops	Crops fed to local livestock because they have failed to meet the standards required to be sold as human food or compound feed ingredients.
Swill	Human food waste from domestic or commercial premises.
Synthetic N	Nitrogen in the form of manufactured fertilizers, such as ammonium nitrate.
Tier levels	Defined in IPCC (2006), these correspond to a progression from the use of simple equations with default data (Tier 1 EFs), to country-specific data in more complex national systems, (Tier 2 & 3 EFs). Tiers implicitly progress from least to greatest levels of certainty, as a function of methodological complexity, regional specificity of model parameters, spatial resolution and the availability of activity data.

Executive summary

BACKGROUND AND PURPOSE

The livestock sector is one of the fastest growing subsectors of the agricultural economy, and faces several unprecedented and concomitant challenges. The sector needs to respond to the increasing demands for livestock products that are arising from population growth and changing consumer preferences. It also has to adapt to changes in the economic and policy contexts, and in the natural environment upon which production depends. At the same time, it has to improve its environmental performance and mitigate its impact on climate.

The pig sector is the biggest contributor to global meat production, with 37 percent in 2010. Chicken meat accounts for about 24 percent. Global demand for pig meat, chicken meat and chicken eggs are forecast to grow by 32 percent, 61 percent and 39 percent respectively during the period 2005–2030. If the greenhouse gases (GHG) emissions intensities (emission intensity; or the kg of GHG per kg of product) of these commodities are not reduced, the increases in production required to meet demand will lead to proportionate increases in GHG emissions.

Improving our understanding of where and why emissions arise in livestock supply chains is an important step towards identifying ways to improve efficiency and reduce emissions intensity. This report presents a life cycle assessment (LCA) of the GHG emissions arising from pig and chicken supply chains. It provides a detailed analysis of emissions according to region, sector and systems of production. In addition to informing efforts to reduce GHG emissions, it is hoped that the assessment will also help inform public debate on this important subject.

Two similar reports on emissions from beef and small ruminant supply chains and from the dairy sector are also available. An overall report providing an overview of results and exploring mitigation potential and options is also available.¹

METHODOLOGY

This analysis is based on a LCA approach and includes: (a) pre-farm emissions arising from the manufacture of inputs; (b) on-farm emissions during crop and animal production; and (c) postfarm emissions arising from the processing and transportation of products to the retail point. Emissions and food losses that arise after delivery to the retail point are not included.

While gases of minor importance have been omitted, the three major GHG in agriculture are included, namely: methane (CH₄), nitrous oxide (N₂O) and carbon dioxide (CO₂).

The Global Livestock Environmental Assessment Model (GLEAM) was developed to carry out this assessment. This model quantifies GHG emissions arising from production of the main livestock commodities: meat and milk from cattle, sheep, goats and buffalo; meat from pigs; and meat and eggs from chickens. The model calculates total emissions and (commodity) production for a given farming

¹ FAO. 2010. Greenhouse gas emissions from the dairy sector - A life cycle assessment. FAO, Rome.
FAO. 2013a. Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. FAO, Rome.
FAO. 2013b. Greenhouse gas emissions from ruminant supply chains – A global life cycle assessment. FAO, Rome.

system within a defined area. The emissions per unit of product can be calculated for combinations of different commodities/farming systems/locations at different spatial scales. Emissions are calculated around the year 2005, the most recent year for which all input data and parameters are available.

In a complex analysis such as this, results are not definitive, but rather the best assessment that could be made and subject to improvement in subsequent revisions. Methodological developments are being developed within the context of the LEAP Partnership (Livestock Environmental Assessment and Performance²), to harmonize metrics and approaches used in the assessment of environmental performance of livestock supply chains, including future updates of this report.

KEY FINDINGS

Overall contribution of the pig and chicken sectors to global GHG emissions

Globally, GHG emissions from pig and chicken supply chains are relatively low.³ Pig supply chains are estimated to produce 0.7 gigatonnes CO₂-eq per annum representing 9 percent of the livestock sector's emissions. Chickens are estimated to emit 0.6 gigatonnes CO₂-eq, representing 8 percent of the livestock sector's emissions. While their emissions are comparatively low, the sector's scale and rate of growth require reductions in emission intensity.

Main emissions sources

Pig supply chains

Feed production contributes 60 percent of the emissions arising from global pig supply chains, and manure storage/processing 27 percent. The remaining 13 percent arises from a combination of postfarm processing and transport of meat (6 percent), direct and indirect energy use in livestock production (3 percent) and enteric fermentation (3 percent).

Of the feed emissions, N₂O resulting from the application of synthetic and organic fertilizers in feed crop production accounts for 17 percent of total pig emissions, while CO₂ from the use of energy in field operations, crop transport and processing, and the manufacture of fertilizer and synthetic feed materials accounts for 27 percent. An additional 13 percent of the total emissions arises from land-use change (LUC) driven by increased demand for feed crops. The remaining feed emissions (3 percent) are CH₄ from flooded rice cultivation.

Total direct and indirect energy consumption across the supply chain⁴ accounts for 37 percent of the total emissions.

Chicken meat and egg supply chains

For chicken meat, feed production contributes 78 percent of emissions, direct on-farm energy use 8 percent, postfarm processing and transport of meat 7 percent and manure storage/processing 6 percent. For eggs, feed production contributes 69 percent of emissions, direct on-farm energy use 4 percent, postfarm processing and transport of meat 6 percent and manure storage and processing 20 percent.

² <http://www.fao.org/ag/againfo/livestock-benchmarking/en/>

³ See FAO (2013) Tackling climate change through livestock. FAO, Rome. for a comparison between commodities and species.

⁴ Energy used (a) pre-farm to manufacture inputs, (b) on-farm in feed and livestock production, and (c) postfarm in transport and processing.

Meat has higher feed emissions than eggs partly because rations for broiler chickens, on average, include a higher share of soybean and therefore more soybean sourced from areas where LUC is taking place. Consequently LUC accounts for 21 percent of meat emissions and 13 percent of egg emissions. Eggs have higher manure emissions because layers have a greater proportion of their manure managed in anaerobic conditions, which lead to higher CH₄ emissions. Feed emissions arising from fertilizer application and energy use are important for both meat and eggs: N₂O from fertilizer application accounts for 32 percent of meat and 30 percent of egg emissions, while CO₂ arising from energy use in feed production accounts for 25 percent and 27 percent for meat and eggs respectively.

Total direct and indirect energy consumption across the supply chain⁵ accounts for 41 percent of the total emissions for meat and 37 percent for eggs.

Summary of the factors influencing emission intensity

Emission intensities can be influenced by a combination of factors, depending on the species, system and region in question. Some of the key factors are summarized briefly below.

Feed conversion ratio (FCR)⁶

As feed production is the activity that produces the most GHG for both monogastric species, the efficiency with which pigs and chickens convert feed into edible products is a key determinant of emission intensity. Due primarily to physiological differences, the individual broiler or laying hen tends to be a more efficient converter of feed into edible products than the growing pig. Furthermore, backyard pigs and chickens have higher FCRs than their commercial equivalents, due to differences in the breeds used, feed quality and availability, and management strategies.

Land-use change

Land-use change arising from increased demand for feed crops is a major driver of emissions, but its quantification is associated with strong methodological and data uncertainty. Pig and chicken that have a higher proportion of their ration consisting of soybean produced in countries where LUC is occurring will tend to have significantly higher feed emissions.

Manure management

Manure emissions are a function of the rate at which volatile solids (VS) or N are excreted, and the rate at which they are subsequently converted to CH₄ or N₂O during manure management. High FCRs and low digestibility of feed tend to produce higher rates of VS and N excretion, and explain, for example, why backyard chickens have higher manure N₂O emissions.

The rate at which VS are converted to CH₄ depends on the way in which the manure is managed and the ambient temperature. Higher temperatures combined with anaerobic conditions in manure management tend to lead to high conversion rates of VS to CH₄.

⁵ Energy used (a) pre-farm to manufacture inputs, (b) on-farm in feed and livestock production, and (c) postfarm in transport and processing

⁶ FCR is a measure of the efficiency with which an animal converts feed into tissue, usually expressed in kg of feed per kg of output (e.g. LW, eggs or protein).

Energy use

When summed across the supply chains, emissions from energy use account for 37 percent of the total emissions arising from production of eggs and pig meat and 41 percent of the emissions from chicken meat. The emission intensity of energy production depends on the types of fuels used and the efficiency of energy conversion and distribution. Furthermore, as most of the energy emissions arise as a result of feed production, FCR is also a key determinant of the energy emission intensity per kg of eggs or meat.

Herd/flock structure

The size of the breeding overhead⁷ is small in commercial pig and chicken systems, and therefore variation in the herd/flock structure has a limited impact on the overall emissions intensity in these systems. However in backyard systems, where death rates are high and fertility rates low, breeding animals make up a greater proportion of herd/flock and therefore variation in the size of the breeding overhead can be a significant influence on emissions intensity.

Variation in emissions intensity between production systems

Pig supply chains

Industrial systems, which account for 60 percent of global production, have lower emission intensities than intermediate systems due to a combination of lower feed conversion ratios, more digestible rations and lower shares of rice products in the ration.⁸

The emission intensity of backyard pigs is lower than the other systems primarily because the emissions per kg of feed are significantly lower for backyard pigs (although the low feed emissions are partially offset by their higher FCRs). The higher FCRs lead to higher rates of excretion of both volatile solids and N per kg of meat produced, which result in higher manure emissions. In addition, backyard pigs are assumed to have negligible emissions arising from LUC or from postfarm processing and transport of meat.

Chicken supply chains

On average, layers have a lower emission intensity than broilers or backyard systems, when measured in terms of emissions per kg of protein. Although layers have higher manure CH₄ emissions than broilers, this is compensated by their lower emissions per kg of feed (as a result of having less soybean in their ration and, consequently, lower LUC emissions) and their lower FCR.

Backyard systems have significantly higher FCRs than layers or broilers due to the lower physical performance. This is exacerbated by the structure of the backyard flocks, which have higher proportions of relatively unproductive breeding animals due to higher death rates and lower fertility rates. The amount of N excreted per kg of protein produced is therefore higher in backyard systems, which leads to higher manure N₂O emissions.

⁷ A number of breeding animals, e.g. sows and boars, are required to produce offspring to maintain the herd. While they perform an essential function, breeding animals are relatively unproductive in terms of the amount of meat or eggs they produce, so these animals (along with the animals reared to replace them) are often referred to as the “breeding overhead”.

⁸ Flooded rice cultivation can produce significant amounts of CH₄, which contributes to a high emissions intensity of the feed ration.

Regional variation in emission intensity

Emission intensities vary between the main producing regions. Differences are mostly explained by variation in feed materials in the ration, animal productivity and manure management.

Pig supply chains

There is significant regional variation in average FCR in backyard systems, which leads to variations in the feed emissions. For example, the FCR of backyard pigs in Sub-Saharan Africa is 35 percent greater than that of Eastern Europe, when measured at the herd level. The variations in FCR arise due to differences in parameters such as genetic potential, nutrition and health status. The regional differences in FCR are less marked in intermediate and industrial systems, reflecting the greater levels of standardization.

For industrial pigs the emissions per kg of feed can vary a great deal between regions, depending on the amount of soybean in the ration, and the proportion of the soybean that is sourced from countries where LUC is occurring. This leads to markedly higher feed emissions for industrial pigs in Latin America and Western Europe. In intermediate systems, the presence of rice feed products leads to significant increases in feed emissions in Asia.

Regions that have higher than average manure CH₄ emissions include: backyard pigs in South Asia (due to high temperatures and high VS excretion rates); intermediate pigs in East and South east Asia (due to high temperatures and liquid manure management); and industrial pigs in North America (due to the use of lagoons/slurry/pits with long storage, and the higher biodegradability of the manure).

Chicken supply chains

There is significant regional variation in average FCR in backyard systems, which leads to variations in the feed emissions. For example, the FCRs of backyard chickens in Sub-Saharan Africa and East and South east Asia are more than twice those in Eastern Europe, when measured at the flock level. As with backyard pigs, the variations in FCR arise due to differences in parameters such as genetic potential, nutrition and health status – with backyard chickens particularly susceptible to disease and predation. In contrast, the regional differences in FCR are negligible for broilers and layers, reflecting the high degree of standardization in these systems.

For broilers and layers, the emissions per kg of feed can vary a great deal depending on the amount of soybean sourced from areas associated with LUC. As with industrial pigs, this leads to higher emissions in regions such as Latin America and Western Europe. In backyard systems, the CO₂ emissions arising from energy use in field operations are lower in regions such as Sub-Saharan Africa and Asia, where a significant proportion of the work is undertaken using animal draft power. Finally, feed N₂O varies between regions in response to differences in the rates at which nutrients are applied to, and used by, crops.

Manure N₂O emissions in backyard systems are higher in Sub-Saharan Africa and Asia, due to the higher FCRs in these regions. For layers, manure CH₄ emissions tend to be lower in regions where solid storage (i.e. North America and South Asia) or drylots (Eastern Europe) predominate.

CONCLUSIONS

The range of emission intensity, both across and within supply chains, suggests that there is room for improvement. The following areas show particular promise for reducing emissions:

- reducing LUC arising from feed crop cultivation;
- improving the efficiency of crop production, particularly improving fertilization management;
- improving the efficiency of energy generation and supply, and of energy use, both on-farm (in housing and field operations) and off-farm (manufacture of agricultural inputs, and transportation and processing of farm products);
- reducing use of uncovered liquid manure management systems (MMS), particularly in warm climates;
- improving feed conversion of the individual animal (through, for example, better breeding techniques) and also of the herd (by reducing losses to disease and predation, particularly in backyard systems);
- providing balanced animal nutrition.
- Finally, it should be borne in mind that this report focuses on a single measure of environmental performance: kg CO₂-eq/kg commodity. When evaluating GHG mitigation measures, attention should be paid to the potential impacts on other policy objectives, such as sustaining water resources, improving food security and reducing poverty.