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Resource use and environmental impacts from Australian chicken meat production

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ABSTRACT

Agri-food industries such as chicken meat production face increasing pressure to quantify and improve their environmental performance over time, while simultaneously increasing production to meet global demand. Using life cycle assessment, this study aimed to quantify resource use, environmental impacts and hotspots for Australian chicken meat production using updated inventories and new methods. Two contrasting states; Queensland, and South Australia, and two housing systems; conventional and free range were analysed to indicate the variation expected between regions and systems. Lower impacts were observed per kilogram of chicken meat produced in South Australia compared to Queensland for fossil fuel energy, greenhouse gas (including land use and direct land use change) and fresh water consumption (18.1 and 21.4 MJ, 2.8 and 3.4 kg CO_2-e, 38 and 111 L respectively), but not arable land or stress weighted water use (22.5 and 14 m^2, 36 and 26 L H_2O-e respectively). Feed production was the largest contributor to all impact categories, and also showed the largest variation between regions, highlighting the importance of spatially specific feed grain datasets to determine resource use and greenhouse gas from chicken meat production. While the feed conversion ratio was lower in South Australia, this was found to be less significant than differences related to crop yield, irrigation water use and the use of imported feed ingredients, suggesting that incremental improvements in feed conversion ratio will result in lower impacts only when feed inputs and production systems do not change. Fresh water consumption was lower in South Australia, but did not correlate with stress weighed water use (lower in Queensland), highlighting that volumetric water use is not a reliable indicator of the impact of water use. We did not observe substantial differences between conventional and free range production when feed related differences were removed, because key productivity factors such as feed conversion ratio were similar between the two housing types in Australia. While results were found to vary between regions, total greenhouse gas emissions were low from these Australian supply chains, and resource use was moderate. Expansion of the study to include additional regions and impact categories is recommended in future benchmarking studies.

1. Introduction

Food production supply chains face increasing pressure over the utilisation of scarce resources and the generation of environmentally relevant emissions, and global initiatives have been initiated to benchmark the impact of livestock supply chains on climate change (MacLeod et al., 2013) and other impacts. Life cycle assessment (LCA) has been widely used to benchmark the environmental performance of supply chains globally. However, the lack of internationally agreed methods can make comparison difficult (De Vries and De Boer, 2010.). In Australia, a series of studies investigating regional or national livestock production systems, using broadly comparable methods, have been completed by the authors and others. These studies include regional beef and lamb production (Ridoutt et al., 2012; Wiedemann et al., 2015b) and pork production (Wiedemann et al., 2016a). These studies provide a regional knowledge base for understanding the environmental impact of Australian meat production, but there is a need for more studies focussing on poultry production. Future increases in global demand for grain and meat (FAO, 2009) are expected to result in greater pressure on water and arable land. Most LCA research in Australia has focussed on greenhouse gas

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(GHG) emissions and this is an acknowledged issue of global significance. Because in Australia water is a scarce and heavily allocated resource (MDBA, 2012) and arable land represents only a small fraction of the total land mass available (Lesslie and Mewett, 2013), and further research is needed in these areas.

The Australian chicken meat industry is vertically integrated with modern, efficient production systems that aim to maximise the environmental efficiency of their production systems. Feed conversion ratio in chicken meat production is low relative to other species, resulting in lower impacts via feed production. Because of the controlled nature of production, where most birds are housed in-doors, the direct impacts are also minimised. However, few data are available to quantify the performance of the industry or the contribution of impacts from each stage in the supply chain. One study (Bengtsson and Seddon, 2013) investigated the impacts of chicken meat production from a large, vertically integrated company in Australia, and a number of chicken meat LCAs have been completed elsewhere in the world (i.e. Leinonen et al., 2012; Pelletier, 2008). These studies highlight the significance of feed production as a major contributor to GHG and nutrient related impacts from chicken meat production, though in most cases a comprehensive assessment of primary resources, viz; energy, water and land was not included. These studies have shown that GHG impacts from chicken meat arise predominantly from soil nitrous oxide and fossil fuel use in crop production and housing, and manure related emissions. Most chicken meat studies (i.e. Leinonen et al., 2012; Pelletier, 2008; Williams et al., 2006) did not include impacts from meat processing, even where results are reported on a carcase weight (CW) basis, and consequently, energy and water use from this stage may have been underestimated. Because of the low input nature of Australian grain production and predominantly dry soil conditions, soil nitrous oxide and fuel use in Australian crop production may be much lower than other regions of the world, corresponding to lower feed related GHG emissions. Conversely, electricity related emissions are high in Australia because of the reliance on coal fired electricity generation, which will therefore result in higher impacts from energy intensive stages in the supply chain, such as housing and meat processing in Australia. This study aimed to determine GHG, fresh water consumption, fossil energy demand and land occupation to provide a benchmark for Australian conventional and free range production, and determine impact hotspots in the supply chain, by applying methods and inventories representative of Australian production and processing. The study included two major, contrasting production regions and collected data from multiple companies, to provide results that are broadly representative of Australian chicken meat production.

2. Materials and methods

The study utilised primary and secondary data sources and methods reflecting Australian production systems where available. Specific data collection and modelling approaches are outlined in the following sections.

2.1. Impacts assessed

The study assessed GHG emissions using the IPCC AR4 global warming potentials of 25 for CH_4 and 298 for N_2O, as applied in the Australian National Inventory Report (NIR) (Commonwealth of Australia, 2015b). GHG emissions associated with land use (LU) and direct land use change (dLUC) were included and reported separately, following guidance from the Livestock Environmental Assessment and Performance partnership (LEAP, 2014). Fossil fuel energy demand was assessed by aggregating all fossil fuel energy inputs throughout the system and reporting these per mega joule (MJ) of energy, using lower heating values (LHV). Fresh water consumption (L) was assessed using methods consistent with ISO (2014), as described in the following sections. One exception was the assessment of fresh water consumption associated with land use change (LUC) which was not assessed because of the lack of suitable inventory data for the background grain processes. The impact on water use was assessed using the stress-weighted water indicator, based on Pfister et al. (2009). The value was expressed as a water equivalent (H2O-e; Ridoutt and Pfister, 2010), by dividing the stress weighted water value by the global average water stress volume. Land occupation was assessed by aggregating impacts throughout the supply chain, and both total land occupation and arable land occupation are reported in square meter years (m^2 yr). All modelling was carried out using SimaPro™ 8.0 (Pré-Consultants, 2014) and the study applied an attributional modelling approach.

Production from two Australian states (Queensland – QLD and South Australia – SA) and two production systems: conventional housing (indoor housing with tunnel ventilation), and free range (FR) production were investigated. Queensland is located in the mid-north eastern part of Australia, while SA is located in the southern-central part of the continent. Each production region mainly utilised feed produced in the region, though the QLD supply chain utilised slightly more imported feed ingredients. The primary production supply chain included breeding (rearing of parent birds, fertile egg production and hatchery processes), grow-out and meat processing, with all associated inputs. Grandparent and great grandparent breeding systems were not included since they were found to contribute <1% of impacts, in a preliminary scoping analysis conducted as part of the study (unpublished data). Data were collected as part of the study to cover a 12 month production period (2009–2010), from three major vertically integrated poultry producers across 38 facilities. The FR supply chain consisted of one company supply chain in each state, each with multiple FR farms. These were combined to ensure company data were confidential, and to provide a larger and more representative FR dataset. However, a limitation to this was that we could not compare conventional with FR production within each state supply chain. Data collection processes are described in the following sections. The end-point of the supply chain was the cold storage unit where chicken meat is stored prior to wholesale distribution. Results are presented using two functional units (FU): 1 kg of chilled chicken (whole bird) ready for packaging and distribution to retail, and 1 kg of boneless, skinless chicken portions, ready for packaging and distribution to retail. The system boundary of the study is shown in Fig. 1.

2.2. Life cycle inventory

The inventory was separated and reported separately for each stage of the supply chain. Data collection methods and calculation methods are described in the following sections.

2.2.1. Feed use and milling

Feed use for breeding birds and meat chickens was reported by each company, in each state. Birds are phase fed, and diets may change during the year in response to changes in the availability of commodities. Each company operated their own feed mill, and commodity inputs, energy and water use, and transport distances were reported by each feed mill over a 12 month period (Table 1). The aggregated rations are shown in Table 2.

2.2.2. Feed production

Major feed grains were modelled for Australian grain processes by the authors, or using processes available from the AustLCI