Reconsidering the contribution of Canadian poultry production to anthropogenic greenhouse gas emissions: returning to an integrated crop–poultry production system paradigm

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ABSTRACT

Public discourse around “greenhouse gases” (GHG) has led to the application of life-cycle assessments to ascertain the “global warming potential” of human activities. Life-cycle assessments applied to agricultural systems typically do not consider positive contributions (i.e., fixation of atmospheric carbon dioxide (CO2)) or consider complex interrelationships among commodities within the larger agricultural sector. The purpose of this article is to present an argument for a paradigm shift and that poultry production should be considered as a value-adding activity within modern crop production systems for GHG footprinting purposes. To this end, a case study based on 2018 production data is presented where poultry production (chicken and eggs) was contextualized as a sub-component of wheat and corn production in the Canadian provinces of Alberta and Ontario, respectively. Total GHG footprint was calculated to be 3.05 and 3.29 million tonnes (MT) of CO2 equivalent (eq) for Alberta wheat and Ontario corn production, respectively. The GHG footprint of chicken production was calculated to be 0.39 and 1.38 MT CO2 eq in Alberta and Ontario, respectively. The GHG footprint of egg production calculated to be 0.12 and 0.47 MT of CO2 eq in Alberta and Ontario, respectively. When carbon (C) fixation as crop biomass is included in the scenario, the combined crop-poultry system C balance in 2018 favored net fixation of 40.70 and 35.15 MT of CO2 eq in Alberta and Ontario, respectively. The calculated total GHG footprint of poultry production in Alberta and Ontario corresponded to only 1.2 and 5.5% of the calculated total net CO2 fixation of their respective cropping systems. This case study demonstrates that by failing to acknowledge real world estimates of C fixation by crop biomass, GHG footprinting exercises largely misrepresent reality and can thus perpetuate faulty assumptions about the environmental footprint of animal agriculture. The authors propose that the calculations presented herein provide grounds to postulate the hypothesis that modern, integrated crop-livestock agricultural systems in Canada (and elsewhere) act as net sinks for atmospheric CO2.

Key words: carbon-fixation, chicken, crop, egg, greenhouse gases emissions

INTRODUCTION

The ongoing discussion within society regarding anthropogenic emissions of greenhouse gases (GHG) has led to the broad application of life-cycle assessments (LCA) to ascertain the global warming potential for a range of human activities.

The LCA process models the environmental impact of production systems by subdividing them into their constituent components or activities and scrutinizing the individual impact of each activity (Horne et al., 2009). Essential components of LCA include establishing the boundaries of the system under consideration, selection of the “functional unit” or unit of production emerging from the system to serve as the basis for the calculated impact, and sourcing robust data pertaining to each stage of the system’s life cycle (International Standards Organization, 2006). Whereas LCA provides a convenient and standardized methodology to estimate environmental impact, they are characterized by the same limitations common to other modeling processes. Notarnicola et al. (2017), for instance, noted that LCA outputs are open to misinterpretation if the defined boundaries around the system are inappropriately selected or if the data used to model the system are
incomplete or have large uncertainty associated with them. It is important therefore to scrutinize the assumptions and underlying data when evaluating the accuracy, relevance, and outputs of LCA modeling exercises.

Since the early 2000s, there has been a rapid expansion of the use of LCA in the agricultural sector to calculate the environmental impact of a wide range of livestock commodities. Case studies have been completed for a variety of commodities, jurisdictions, and under a wide range of conditions (De Vries And de Boer, 2010). In general, there is heterogeneity in reported GHG outputs from LCAs conducted on the same commodity and using the same functional unit (Lopez-Andres et al., 2018), which likely trace their origin to the aforementioned factors. This discrepancy has led to calls for greater standardization of LCA methodologies applied to livestock (Herrero et al., 2011).

A major notable deficiency of LCA applied to agricultural systems is that they do not generally consider positive contributions (i.e., fixation of atmospheric carbon dioxide $[\text{CO}_2]$) to GHG fluxes. Agriculture and forestry are distinct from all other large-scale human activities in that both remove large quantities of $\text{CO}_2$ from the atmosphere each year, converted primarily to plant biomass and soil organic carbon (C). For instance, Kurz et al. (2014) estimated that Canada’s managed boreal forests are net sinks for atmospheric $\text{CO}_2$ in excess of 100 million tonnes (T) of $\text{CO}_2$ equivalents (eq) per year. Similarly, Fan et al. (2019) proposed that Canadian agricultural acreage has gone from being a net emitter of GHG in 1990 to a net sink for more than 380 million T of CO$_2$ eq per year. This estimate is equivalent to more than half of Canada’s estimated total anthropogenic GHG emissions (Environment and Climate Change Canada, 2019). Consideration of the $\text{CO}_2$ fixation from managed landscapes should therefore feature prominently into any balanced discussions of GHG emissions from agriculture and/or forestry.

A characteristic common to most LCA of agricultural systems is that the boundaries do not take into consideration the complex interrelationships among commodities within the larger agricultural sector (van Hal et al., 2019). The specialization of farms into either crop or livestock commodities that has occurred over the past several decades (Statistics Canada, 2019a) obscures the indisputable reality that crop and livestock production are still highly interdependent, though more commonly at a regional rather than farm level.

The economics of crop production are dependent on the existence of local feed markets to absorb and utilize crop tonnage that would be of insufficient quality for human food and or export. In Canada, for example, the domestic feed market absorbs approximately 4 million T of non-human feed grade wheat annually (Statistics Canada, 2019b). Livestock feed markets also support domestic processing activity by absorbing high value co-product tonnage. For instance, Canadian domestic canola crushing activity generates more than 5 million T of co-product meal, of which domestic livestock production utilizes 606,000 T and foreign feed markets absorb much of the remainder (Canola Council of Canada, 2019).

The economics and sustainability of specialized poultry (and swine) sectors are, in turn, heavily dependent on the availability of local feed-grade grains and processing co-products. Feed represents the single greatest cost of production (Lachapelle, 2014), and the availability of cropland acreage near intensive livestock operations is of paramount importance for sustainable manure management (Sauer et al., 2000). Regions and countries that are net importers of feedstuffs to sustain domestic livestock production are susceptible to net accumulations of nitrogen and phosphorus in agricultural soils (Wang et al., 2018) and therefore incur the accompanying environmental risks. In consideration of these realities, it is reasonable to posit that GHG emissions from poultry production should be viewed in the context of regionalized, integrated crop–poultry production systems.

The purpose of this article therefore is to present an argument for a paradigm shift in how GHG emissions from poultry production should be considered. Specifically, poultry production in this article will be contextualized as a value-adding activity integrated within modern crop production systems, rather than as an activity conducted in isolation. In support of this argument, the authors present a crude but empirically-based estimate of the net C balance of integrated grain crop–poultry production systems in 2 representative Canadian jurisdictions. These calculations differ from conventional LCA processes as they take into account both estimated LCA-based GHG emissions as well as estimates of atmospheric $\text{CO}_2$ fixation.

**METHODS AND MATERIALS**

**Data Sources**

All data sources utilized in this study are in the public domain and are fully available for verification purposes.

Data pertaining to production tonnage of corn grain ($\text{Zea mays}$) in the province of Ontario and of wheat ($\text{Triticum aestivum}$) in Alberta, both for the 2018 crop year, were drawn from the agricultural statistics database maintained by the Government of Canada (Statistics Canada, 2019c). Production of both crops is expressed in metric T of grain (Table 1).

Data regarding chicken and egg production in both Alberta and Ontario for the 2018 calendar year were obtained from Agriculture and Agri-Food Canada (2019) and Statistics Canada (2019d), with supporting information from the Chicken Farmers of Canada (2019) and the Egg Farmers of Canada (2019); (Table 1). Chicken production is expressed in kg of liveweight, whereas egg production is expressed in dozens of eggs, as these are the respective bases on which producers in Canada are compensated.

Egg production was further adjusted using the weight grade statistics from each province and
Canadian weight grading standards (Egg Farmers of Canada, 2019). The weight grade distribution among the Grade A categories resulted in total egg production in Alberta and Ontario being multiplied by correction factors of 0.99 and 1.00, respectively, to express production in dozens of large eggs (average weight of 59.5 g/egg or 714 g/dozen).

LCA-Based Estimates of GHG-Emissions of Crops and Poultry Products

Carbon footprints (kg of CO₂ eq/T grain production) for corn and wheat grain crops were taken from a recent report by the Canadian Roundtable for Sustainable Crops (2019); Table 2. Estimates of the GHG footprint of direct energy, fertilizer manufacturing, seed and pesticide, and nitrous oxide (N₂O) contributions were averaged for sites in Alberta (3) and Ontario (2). Estimates of net soil organic C loss/deposition were also drawn from the same report. Because of the lack of high-resolution data concerning soil organic C fluxes in situations where there is net accumulation of soil organic C over decadal or multidecadal bases, gains in soil organic C reported in Canadian Roundtable for Sustainable Crops (2019) were not credited against total GHG footprint for wheat grain. Losses in soil organic C reported for corn grain, however, were added to the other GHG footprint components to yield its total GHG-footprint (Table 2).

The LCA-based estimate for chicken production used for balance calculations was that reported by the Chicken Farmers of Canada of 2.4 kg of CO₂ eq/kg of liveweight chicken (Courchesne and Jamaron, 2014; Chicken Farmers of Canada, 2019). The value assumed for eggs was 1.73 kg CO₂ eq/dozen eggs, which is derived from the value reported for the Canadian national average across all housing types by Pelletier (2017).

Stated Assumptions

To complete the balance calculations, it was necessary to make several assumptions regarding C contained in the crops and residues. As per Bolinder et al. (2007), it was assumed that all crop biomass is 45% C on an as-is basis (90% dry matter). This assumption is supported by extensive published data for a wide range of

Table 1. Production of major feedstock crops (metric T grain), chicken (kg liveweight), and eggs (large dozen) in Alberta and Ontario (Canada) in 2018.

| Province        | Commodity              | Production (2018) | % of Canadian production (2018) | Provincial rank (2018) |
|-----------------|------------------------|-------------------|-------------------------------|------------------------|
| Alberta         | Crop products¹         |                   |                               |                        |
|                 | Wheat, T grain         | 8,771,600         | 36.6                          | Second                 |
|                 | Livestock products     |                   |                               |                        |
|                 | Chicken, # head        | 161,083,352       | 9.4                           | Fourth                 |
|                 | Eggs¹, dozen large eggs| 2,257             | 9.2                           | Fifth                  |
| Ontario         | Crop products¹         |                   |                               |                        |
|                 | Corn, T grain          | 8,767,900         | 63.1                          | First                  |
|                 | Livestock products     |                   |                               |                        |
|                 | Chicken, # head        | 576,690,494       | 33.8                          | First                  |
|                 | Chicken, avg. wt per bird (kg) | 235,792,323 | 37.4                          |                        |
|                 | Eggs¹, dozen large eggs| 268,860,409       | 37.4                          | First                  |

¹Source: Statistics Canada, 2019b.  
²Source: Agriculture and Agri-Food Canada, 2019.  
³Source: Statistics Canada, 2019d and Egg Farmers of Canada, 2019. Count was adjusted by distribution of eggs in Grade A weight categories to be expressed as dozens of large (59.5 g/egg) eggs.

Table 2. Total greenhouse gas (GHG) footprint (kg CO₂ eq/T grain production) of major feedstock crops in Alberta and Ontario (Canada), partitioned into major components.

| Crop          | Region             | Direct energy use | Fertilizer manufacturing | Seeds & fertilizer N₂O emissions | Soil organic carbon loss² | Total GHG footprint¹ |
|---------------|--------------------|-------------------|--------------------------|---------------------------------|--------------------------|-----------------------|
| Wheat         | Northern Alberta   | 30.8              | 100.6                    | 16.8                            | 209.0                    | −137.9                | 357.2                |
| Wheat         | Central Alberta    | 37.8              | 92.4                     | 13.4                            | 166.1                    | −153.5                | 309.7                |
| Wheat         | Southern Alberta   | 27.7              | 108.6                    | 19.9                            | 218.8                    | −105.6                | 375.0                |
| Wheat         | Provincial mean    | 32.1              | 100.5                    | 16.7                            | 198.0                    | −132.3                | 347.3                |
| Corn          | Southern Ontario   | 22.9              | 57.1                     | 7.4                             | 179.3                    | 79.9                  | 346.5                |
| Corn          | Eastern Ontario    | 25.5              | 57.1                     | 8.1                             | 181.9                    | 130.4                 | 403.0                |
| Corn          | Provincial mean    | 24.2              | 57.1                     | 7.7                             | 180.6                    | 105.2                 | 374.8                |

¹Source: Canadian Roundtable on Sustainable Crops, 2019.
²Negative values indicate a net gain of soil organic carbon, which are not credited against GHG emissions from other components because of uncertainty with regards to steady-state soil organic C fluxes in reduced tillage systems. Positive values indicate loss of soil organic C, which were added to the other components to yield total GHG.
³Provincial mean values are those assumed for each crop in each province for subsequent calculations (see Table 4).
agricultural and nonagricultural biomass such as those reported by Jenkins et al. (1998), Demirbas (2004), Vassilev et al. (2010), Clark and Preto (2011), Parmar (2017), and Ma et al. (2018). The production tonnage of aboveground and belowground, nongrain residue was estimated for each crop based on the yield ratios of each residue type to grain reported for Canadian-grown crops calculated from Thiagarajan et al. (2018).

Because chicken meat and eggs have a relatively short shelf-life and are highly digestible foodstuffs, it was not appropriate to consider chicken or egg biomass as medium- or long-term storage forms of C. The calculated C mass (CO2 equivalent basis) fixed as chicken liveweight and eggs is therefore reported (Table 2) but is excluded from the overall C balance calculation for the crop–chicken system.

The calculated C content of broiler chicken biomass is based on average market liveweights of 2.25 kg/bird and 2.44 kg/bird in Alberta and Ontario respectively, which were derived from market statistics (Agriculture and Agri-Food Canada, 2019). Values for the amount of protein and fat per chicken marketed in each province were then calculated from empirically derived Gompertz models reported for broiler chickens by Caldas et al. (2019). The estimated protein and fat contents for the assumed market liveweights were 176 g protein/kg BW and 90 g fat/kg BW for Alberta and 177 g protein/kg BW and 91 g fat/kg BW for Ontario (Table 2). The C content of body protein was assumed to be 45.5% C by weight, based on a standard amino acid profile of chicken meat (Health Canada, 2015a) and the relative C content in each constituent amino acid. Likewise, the C content of fat was assumed to be 76.1% by weight, based on a standard fatty acid profile of poultry fat (Health Canada, 2015b) multiplied by the proportional C content in each constituent fatty acid. The resulting calculated C content in each kg of liveweight was 0.549 kg CO2 eq for Ontario and 0.544 kg CO2 eq for Alberta.

The C content of egg (0.423 kg CO2 eq/kg egg mass) was calculated likewise, from the standard protein (105 g/kg egg mass) and fat (89 g/kg egg mass) content reported for a single large egg, corrected for C content of the constituent amino acids and fatty acids according to reported profiles (Health Canada, 2015c).

All C content parameters were converted to a CO2 equivalency by correcting total C content for the relative contribution of C to the molecular weight of CO2 (27.3%).

**RESULTS AND DISCUSSION**

In 2018, Alberta ranked second among the Canadian provinces in the production of wheat, whereas ranking fourth and fifth (out of 10) for production of chicken meat and eggs, respectively (Table 1). In comparison, Ontario was the largest producer of corn, chicken meat, and eggs in Canada in 2018. The slightly greater average weight (and therefore estimated protein and fat content) of chickens at marketing resulted in the average chicken produced in Ontario containing a slightly greater amount of fixed C compared to chickens from Alberta (Table 3). The distribution of egg weights across Grade A weight classes were nearly identical in each province, resulting in identical C fixed per unit of egg mass.

Despite higher direct energy and fertilizer-associated GHG footprints for Alberta wheat, Ontario corn had a greater GHG-footprint per T of grain produced (Table 2). This finding is largely because of the losses in soil organic C per T of corn grain production, which are not mirrored in Alberta wheat grain production because of widespread adoption of conservation tillage and zero-till management of annual crop acreage in Western Canada (Agriculture and Agri-Food Canada, 2016).

More than 8.7 million T of grain was produced in each province in 2018 (Table 4). The aboveground and belowground residue to grain ratios reported by Thiagarajan et al. (2018) for these crops suggest that in the process, a combined 30 million T of nongrain crop biomass were produced in the 2018 crop year. Annual statistics are not routinely kept for the production of residue biomass, as its local economic value (e.g., straw for bedding) often determines whether producers collect it or simply spread it back onto crop acreage. The range of allocation coefficients for wheat and corn grain in Bolinder et al. (2007) suggests that between 27 and 68 of total crop biomass is returned to the soil, depending on the extent to which residues are harvested or

| Province/commodity | Production\(^1\) in 2018, kg | Protein content\(^2\), g/kg | C content of protein\(^3\), % | Fat content\(^4\), g/kg | C content of fat\(^5\), % | C content fixed as egg/chicken biomass\(^6\), T CO2 eq |
|-------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|----------------------------------|
| Alberta Chicken | 161,083,352 | 176 | 45.5 | 90.0 | 76.1 | 87,628 |
| Eggs | 47,234,890 | 105 | 45.4 | 89.0 | 76.2 | 19,982 |
| Ontario Chicken | 576,690,494 | 177 | 45.5 | 91.0 | 76.1 | 316,411 |
| Eggs | 191,906,052 | 105 | 45.4 | 89.0 | 76.2 | 81,208 |

\(^1\)From Table 1. One dozen eggs assumed weight of 714 g.

\(^2\)Derived from Health Canada (2015b,c).

\(^3\)Based on standard amino acid profile (Health Canada, 2015a,c) and proportional C content of constituent amino acids.

\(^4\)Based on standard fatty acid profile (Health Canada, 2015a,c) and proportional C content of constituent fatty acids.

\(^5\)C converted to CO2 basis by dividing by 0.273 (CO2 is 27.3% C by weight).

\(^6\)From Table 1. One dozen eggs assumed weight of 714 g.
removed. In the context of determining real-world C fluxes therefore, the inclusion of non-grain residues in calculations is integral, as they accounted for nearly two-thirds of crop biomass produced in 2018.

Assuming that biomass contains 45% C, the calculations summarized in Table 4 reveal that for each T of GHG (in CO2 equivalents) emitted in the production of these 2 crops in 2018, 14.5 and 11.3 T of CO2 was fixed as crop biomass as the initial condition for these integrated systems rather than the final balance. The natural decomposition rate of aboveground residues, if left unincorporated on the soil surface (as in reduced tillage systems), would however be expected to be very low, as the C:nitrogen (N) ratio therein is much higher than is regarded as optimal for decomposer organisms (Aulakh et al., 1991; Hadas et al., 2004). A portion of the C in consumed grain too would persist postconsumption in the form of digestion-resistant fiber in manure and sewage sludge, whose postapplication decomposition rate in the field would be affected by several factors, including C:N ratio (NRCS, 2011), temperature (Pratt et al., 2002), moisture conditions (Murwira et al., 1990), and aeration (Kulcu and Yaldiz, 2004). A lack of precise, high-resolution data on the fate and disposition of exported grain and life cycle duration of postharvest grain and residue biomass therefore is the largest source of uncertainty in the real-world C accounting for these exemplar integrated systems.

The authors do not propose that all or even a majority of the CO2 fixed by the crop component of these systems would persist beyond a 12-month period (beyond the succeeding harvest), therefore serving as a C sink. The calculations herein, however, indicate that only a small

Table 4. Estimated net carbon balance (T of CO2 eq) of integrated crop–poultry production systems in Alberta and Ontario (Canada) in 2018.

| Parameter | Alberta | Ontario |
|-----------|---------|---------|
| Crop system parameters, 2018 | Wheat | Corn |
| Production1, T grain | 8,771,600 | 8,767,900 |
| Aboveground residue:grain yield2 | 1.48 | 1.05 |
| Belowground residue:grain yield2 | 0.58 | 0.51 |
| Aboveground residue biomass production3, T | 12,981,968 | 9,206,295 |
| Belowground residue biomass production3, T | 5,987,528 | 4,471,629 |
| Carbon fixed4, T CO2 eq | | |
| As grain | 14,458,681 | 14,452,582 |
| As aboveground residues | 21,398,848 | 15,175,212 |
| As belowground residues | 8,386,035 | 7,370,817 |
| Total crop biomass fixation | 44,243,564 | 36,998,611 |
| GHG emissions | | |
| GHG footprint5, T CO2 eq/T grain | 0.3473 | 0.3748 |
| Total GHG footprint, T CO2 eq | −3,046,377 | −3,286,209 |
| Net crop system C balance6, T CO2 eq | 41,197,187 | 33,712,402 |
| Poultry system parameters, 2018 | | |
| Chicken | | |
| Production1, kg liveweight | 161,083,352 | 576,690,494 |
| GHG footprint1, kg CO2 eq/kg liveweight | 2.40 | 2.40 |
| Net chicken system GHG footprint7, T CO2 eq | −386,600 | −1,384,057 |
| Eggs | | |
| Production1, dozen L eggs | 66,155,309 | 268,860,409 |
| GHG footprint1, kg CO2 eq/dozen L eggs | 1.73 | 1.73 |
| Net egg system GHG footprint7, T CO2 eq | −114,449 | −465,129 |
| Net poultry system C balance6, T CO2 eq | −501,049 | −1,849,186 |
| Overall crop–poultry system C balance6, T CO2 eq | 40,696,138 | 35,149,425 |

Abbreviations: GHG, greenhouse gases.
1From Table 1.
2Source: Table 2 in Thiagarajan et al., 2018.
3Estimated residue biomass production = grain production × residue:grain yield ratio.
4Carbon fixed = (Tonnage × 0.45)/0.273.
5From Table 2.
6Positive value indicates net CO2 fixation as biomass, negative value indicates net GHG emissions (as CO2 equivalents).
7Sources: Chicken Farmers of Canada, 2019, and Pelletier, 2017.
8Negative value indicates net emissions of GHG. Sum of total GHG footprint of chicken and egg production.
9Sum of net crop system C balance and net poultry system C balance. Positive value indicates net CO2 fixation by the overall crop–poultry system.
Owing to the large margin between CO₂ chicken liveweight and eggs used in the calculations, the contribution of feed to the overall GHG footprint for poultry diets, the authors chose not to correct for the uncertainty over actual usage of wheat and corn in estimates for the relative contribution of feed along with processing and holistic assessment of the net environmental impact of poultry and livestock production as they pertain to ongoing climate change policy discussions.

The relative contribution of feed to the overall GHG footprint of poultry production reported in the literature varies widely. Feed has been reported to constitute anywhere from 32% (Courchesne and Jamaron, 2014) to 93.7% (Skunca et al., 2015) of the total GHG footprint of chicken meat. Relevant estimates for egg production are somewhat less variable, with values ranging from 65% (Courchesne et al., 2014) to 70% (Pelletier, 2017), though few other LCA described in the literature report the relative contribution of feed to total GHG footprint of eggs. Where most LCA studies agree is that more than 90% of the GHG footprint of feed is directly attributable to the GHG footprint of the principal feed ingredients, with only minor contributions from processing and transport. For a proper accounting of C flux in the crop–poultry system, the contribution of crop-derived feedstuffs to the overall GHG footprint of chicken liveweight and eggs should therefore be removed, as the GHG footprint of the feed crops is already counted in the net balance calculation for the cropping component of the integrated system. Because of the wide range of estimates for the relative contribution of feed along with uncertainty over actual usage of wheat and corn in poultry diets, the authors chose not to correct for the contribution of feed to the overall GHG footprint for chicken liveweight and eggs used in the calculations. Owing to the large margin between CO₂ fixation and GHG emissions (widely favoring the former) in the integrated crop–poultry system however, this correction or lack thereof would have had little effect on the ultimate outcome of these calculations.

CONCLUSION

In conclusion, the current public concern around GHG emissions mitigation has placed increased scrutiny on all large-scale human activities and their impact on the environment. The boundaries that have been used by LCA models of agricultural commodities appear to be at odds with the symbiotic co-existence and complementarity characteristic of modern livestock and crop production. Further, by failing to acknowledge real world estimates of C fixation by crop biomass, GHG foot-printing exercises run the risk of misrepresenting reality. Because GHG foot-printing is increasingly finding its way into public discourse around climate change policy, exclusion of C fixation perpetuates a faulty assumption that agriculture (and more specifically, animal agriculture) is a net contributor to the problem of GHG emissions, rather than part of a combined solution.

While the calculations presented herein are relatively simplistic, the authors propose that they provide sufficient grounds to postulate the hypothesis that modern, integrated crop-livestock agricultural systems in Canada (and elsewhere) act as net sinks for atmospheric CO₂. The authors encourage further discussion and research into this specific question and a more vigorous, balanced, and holistic assessment of the net environmental impact of poultry and livestock production as they pertain to ongoing climate change policy discussions.

ACKNOWLEDGMENTS

The authors would like to thank our colleagues at Alberta Agriculture and Forestry who reviewed our calculations, assumptions, and provided input to improve this manuscript.

Conflict of Interest Statement: The authors did not provide a conflict of interest statement.

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