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Comparative Global Warming Potential as Environment Protection Criteria of Production Systems: A Case Study of Philippine Chicken Meat Sector

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Abstract

Demand for chicken meat has been increasing tremendously over the years globally at an average 2.4% per annum and in the Philippines at an average of 3.4% per annum. In view of the sustainable development goal (SDG) 13: Climate Change, the chicken meat sector needs to embark on more efficient production. It is not just about producing enough food, but doing it in a sustainable way. This study aimed to demonstrate the identification, evaluation and comparison of the environmental impacts of Philippine chicken meat production systems. The analysis was done through the cradle-to-gate life cycle assessment (LCA) methodology and supported with the global livestock environmental assessment model interactive (GLEAM-i) system. The study evaluated 4 production systems in various sites, namely A: intensive broiler operations; B: small-scale broiler operations with own organic feeds; C: backyard free-range operations with own organic feeds; and D: backyard free-range operations using commercial feeds. Based on a functional unit of 1 kg carcass weight (CW), the respective equivalent global warming potential (GWP) were established. System A (5.0 kg CO_2-eq kg^{-1} CW) has the lowest GWP, followed by B (5.15 kg CO_2-eq kg^{-1} CW), D (9.79 kg CO_2-eq kg^{-1} CW) and C (13.51 kg CO_2-eq kg^{-1} CW). Through LCA, the identified improvement opportunities include using locally sourced alternative for feed ingredient for A; increasing production yield to maximize the fixed inputs for B and C; and using locally sourced feed alternatives and increasing production yield for D. Well-established GWP indicators can help in shaping production and consumption patterns. It can help producers in improving operations and in establishing transparency and competitive advantage. While for consumers, it can make them well-informed and empowered in making eco-conscious purchases. This can have a long-term effect on awareness and involvement in environmental protection initiatives among producers, consumers and other concerned groups.

Keywords: Global warming potential; GLEAM-i; Philippine chicken meat sector; Environmental protection; Life cycle assessment

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Introduction

As of 2018, the global average meat consumption is 34.7 kg per capita. Among meat categories, chicken takes the lead with 14.2 kg per capita, followed by pork with 12.3 kg and beef with 6.4 kg. Chicken has been growing by 2.4% per annum over the last decade, while pork is growing at 0.5%. However, beef and veal consumption are declining at 0.8% [1].

Being part of the food and agriculture industry, the chicken meat sector shares the primary concern of securing enough food, both in quantity and quality. However, based on the sustainable development goals (SDGs) [2], the challenge is not just to produce enough food, but to do it in an environmentally, economically and socio-culturally sustainable way. One of the key SDGs that concerns any producing industry is SDG 13: Climate Change. It strongly campaigns for the environmental impact consciousness of human activities that causes changes in the earth's temperature. This is overarching to other goals, such as SDG 2: Zero Hunger that clearly states the need to end hunger, achieve food security and improved nutrition and promote sustainable agriculture; and SDG 12: Responsible Consumption and Production that promotes reduction on ecological footprint by changing the way goods are produced, sourced and consumed. This poses a challenge for the production sectors in food and agriculture since they utilize and convert a lot of raw materials and inputs to have various outputs across the supply chain.

For environmental impacts of chicken production, various life cycle assessment studies have been done among developed nations like in USA, Europe, Brazil, Australia [3–7] and a few among Asia [8–9]. Common key finding is that environmental impacts mostly come from feed production, manure management, and utilization of fossil fuels. Acknowledging the huge environmental impact of chicken and other livestock, advocacies and studies have proposed sustainable approaches in the context of meat reduction or replacement of other protein sources such as plant-based meat, cultured meats and other novel alternatives [10-14]. However, the implications of environmental impact to push for sustainable approaches are not well contextualized, especially among non-specialist sectors, producers and consumers. In most studies, the scientists, researchers and specialists presented the context of environmental evaluation with potential impacts on abiotic depletion potential, acidification potential, eutrophication potential, global warming potential, photo-oxidant formation potential and cumulative energy demand. Most of them are complex terms that are difficult to understand and generate given the limitations on substantial technical knowledge, access on LCA software such as SimaPro, GaBi and the like.

In 2016, the Food and Agriculture Organization of the United Nations (FAO) launched the Global Livestock Environmental Assessment Model interactive (GLEAM-i) [15]. Its objective is aligned to SDG 13 in the reduction of greenhouse gas (GHGs) emissions in livestock activities, to become more productive and more climate conscious. The interactive tool was conceptualized to be user-friendly among farmers, policymakers, scientists, specialists and non-specialists. It can be used with Excel software and can be used offline. The livestock variables are relevant to specific regions, countries and conditions. Versus LCA software used in prior studies, GLEAM-i databases are more country and topography specific. It was designed to complement in providing spatially and temporally consistent references. It also has standard referencing approaches in building its variables and databases. Furthermore, it has the facility to build scenarios, which can be compared from baseline averages or measured for potential impact of mitigation [16]. However, its functionalities are not yet fully disseminated and optimized in evaluating environmental studies.

Background of Philippine chicken meat

Just like the rest of the world, chicken is the most progressive animal enterprise in the Philippines. It continues to be a significant contributor to the agriculture sector. The industry volume is growing at average of 3.4% per annum for the past five years. As of 2018 the total chicken volume production in the Philippines was 1.84 M metric tons. For total inventory, it was recorded at 147.56 M birds, comprising 44% broiler and 56% backyard (native/improved) breeds [17]. In terms of consumption, per capita at 13.01 kg and continues to rise at 3.8% per annum for the last five years. It is basically driven by the increasing population of 1.72% per annum [18], coupled with increasing healthy lifestyle, and increasing fast food consumption in retail and modern trade outlets [19–20].

In terms of scale, the industry is characterized as commercial and backyard farms or production systems. Commercial farms are between medium to big or intensive scale, which have at least 1,000 broilers, or combination of 100 broilers and 100 layers. Most big scale farms are contracted by corporate integrators, which have their own breeder farms and feed mills. They are vertically integrated from the production and marketing of broilers, the importation of grandparent and parent stocks, and the manufacturing and sales of commercial mixed feeds. Primarily, commercial farms raise chicken for sale to processors and retailers. These farms have organized production systems supported with farm records, systems, standards and compliances. On the other hand, backyard is small-scale. As described by Sikap/Strive Foundation, rural families run the typical backyard farms. These comprise around 100 birds of native or improved breeds, which are raised primarily for their own consumption. Also, these farms keep the birds in small housing or let have them roam in a free-range. They can make their own feeds or buy ready mix instead. In terms on business activities, they are not well-structured; may have inadequate farm records; and may have limited compliances on business permits, environmental certificates and labor standards [21–22].

The produce from small-scale and backyard systems have been seen as healthier options. The organic and free-range are becoming more popular with the increasing health- and eco-consciousness among Filipino consumers [23]. It is deemed to be natural and free from growth enhancers, unlike the commercially produced chicken meat. It is also seen as a more sustainable choice since it promotes animal welfare [24–25] with cage-free barn set-up or free-ranging activities. Furthermore, it encourages local economy and livelihood especially among rural areas. This is favorable to small-scale farmers and growers. However, the absence of indicators makes the producers unaware of the environmental impacts of their practices, as well as, the consumers in their supposedly eco-conscious purchases.

From an extensive search of related literature, there are no available environmental impact studies on chicken meat production in the Philippines. There are no substantial information and methods for producers and non-specialists in doing such in the Philippine setting. With these gaps, this study was guided by the following research questions: What would be a practical, user-friendly and relevant sustainability evaluation for chicken meat production in the Philippines? How can production systems be improved to lessen environmental impacts? How do producers and consumers know which chicken meat is more environmentally sound? This study aimed to demonstrate in identifying, evaluating and comparing the environmental impacts throughout the life cycle of chicken. This covered 4 production systems to differentiate and relate the impacts based on varying activities, inputs and activities. The results of this study are significant as reference for the chicken sector.

Materials and methods

1) Study sites

To compare and contrast, this study covered commercial, small-scale and backyard productions. The commercial operations is characterized by System A, an intensive broiler operations. Since intensive farms are usually under a corporate integrated operations with standard procedures, the results in System A represents commercial production. System B is a hybrid small-scale broiler with organic feeds production system. In terms of size, it cannot be categorized as commercial, while in terms of breed it cannot be categorized as backyard. For backyard systems, two farms were considered to denote the varying approaches in production. Presented in Table 1 is the summary profile and description of each system.

Table 1 Description and profile of each production system

Systems	A	B	C	D
A. General information				
Production system	Intensive broiler	Small-scale broiler with own organic mix feeds	Backyard free range with organic feeds	Backyard free range using commercial feeds
Location	Tugbok, Davao City	Panabo City, Davao Province	Toril, Davao City	Argao City, Cebu Province
Broiler breed type	Cobb	Hubbard	Davoc	CZ F1
Number of birds per batch	18,000.0	150.0	82.0	200.0
Average age per cycle	30.0	60.0	90.0	90.0
Production cycles per year	7.5	5.0	3.0	3.0
Feed to gain ration	1.4	2.1	3.1	2.7
Average mortality rate (%)	2.0	5.0	10.0	5.0
Final weight (kg)	1.5	1.2	1.0	1.5
Dressing percentage (%)	80.0	80.0	71.0	71.0
B. Building and space distribution				
Surface of the farm (m^2)	28,650.0	600.0	2,000.0	5,000.0
Building (m^2)	1,848.0	48.0	300.0	10.0
Density indoor (birds m^{-2})	12.0	3.1	-	-
Surface for pasture, if applicable	-	-	1,000.0	1,000.0
Density outdoor (birds m^{-2})	-	-	0.1	0.2
C. Transportation mode				
Breeder to farm	closed van	truck	-	truck
Feeds supplier to farm	winged van	truck	pick-up	motorcycle
Farm to slaughterhouse	harvester truck	-	-	-
Farm to manure buyer	truck	-	-	-
D. Distance (km)				
Breeder to farm	4.0	35.0	-	37.0
Feeds supplier to farm	35.0	3.0	30.0	3.0
Farm to slaughterhouse	8.0	-	-	-
Farm to manure buyer	100.0	-	-	-

The authors recognize that across commercial, small-scale, and backyard systems, there are other farms which may not be fully represented by the four farms. However, this study was limited to the 4 mentioned systems that consented interviews, visits, and evaluation. Moreover, the key objective of this study was to demonstrate how environmental impacts can be measured and compared. Hence, the 4 farms would be substantial. In terms of scope, analysis was limited to meat production. Hatchery, egg production and other activities were not included. Also, no post-farm analysis were included such as slaughterhouse and distribution activities due to data limitations.

2) Life cycle assessment

This study utilized Life Cycle Assessment (LCA) methodology [26]. Following the ISO 14001:2015 standard requirements [27], the process of determining environmental aspects was divided into 4 major phases, namely: goal and scope, inventory analysis, impact assessment and interpretation.

2.1) Goal and scope

The goal was to establish the environmental impact of different chicken production systems. The scope is represented by the system boundary, as illustrated in Figure 1.

This boundary considered the feeds production and farm operations only. Hence, this study followed the cradle-to-gate analysis for the 4 respective production systems. The typical inputs and output of all materials and energy used and produced in a production system are presented in Figure 1. Included in the inputs were the chicks, sawdust for beddings, feeds, electricity, water and fuel used in transportation. For the outputs, the system produces the chicken, manure and the organic fertilizer. Also, the generated GHG gases from the inputs are included as outputs. During the rearing periods, vaccines and antibiotics are administered. However, they were not included due to limited information. Other minor inputs such as cleaning agents were also excluded to simplify the analysis.

2.2) Inventory analysis

The relevant data for life cycle inventory were collected through interviews and visits to the respective farms. Presented in Table 2 is summary of feeds and feeding profile, manure management, beddings and utilities of the 4 systems.

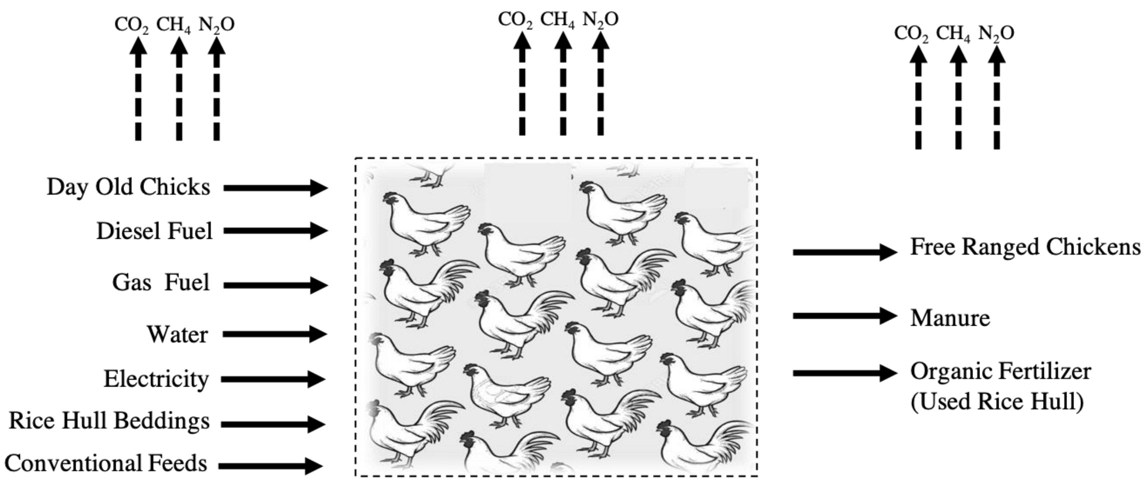

Figure 1 Cradle-to-gate system boundary of chicken farm.

Table 2 Summary of feeds and feeding profile, manure management, beddings and utilities of the 4 systems

Systems	A	B	C	D
A. Feeds and feeding profile				
a) Feed mix	Commercial	Own mix	Own mix	Commercial
b) Ingredients in %	100.0	100.0	100.0	100.0
Yellow corn/corn meal	51.0	30.0	28.0	51.0
Rice bran	9.0	30.0	26.0	9.0
Copra	4.0	8.0	25.0	4.0
Fish meal	5.0	10.0	-	5.0
Soybean meal	25.0	-	-	25.0
Vegetable oil	2.0	-	-	2.0
Protein concentrate	-	-	9.0	-
Dicaphos	1.0	1.0	-	1.0
Calcium carbonate	1.0	1.0	-	1.0
Fermented vegetables	-	15.0	10.0	-
Other additives	2.0	5.0	2.0	2.0
Fermented juice	-	Yes	Yes	-
Natural forage	-	-	Yes	Yes
c) Duration (days)	30.0	60.0	90.0	90.0
Booster	14.0	15.0	30.0	28.0
Starter	7.0	30.0	30.0	35.0
Grower/finisher	9.0	15.0	30.0	27.0
d) Amount (kg)	2.0	2.5	3.0	3.9
Booster	0.5	0.4	0.3	0.3
Starter	0.5	1.2	1.0	1.5
Grower/finisher	1.0	0.9	1.7	2.1
B. Manure management				
a) Manure collection	litter on bedding, every 15 days dried, sacked and disposed for fertilizer	litter on bedding	direct to the ground during foraging while on bedding when inside the barn	direct to the ground during foraging while on bedding when inside the barn
b) Manure disposal	truck pulls out sacked manure after every cycle	used as fertilizer in farm	used as fertilizer in farm	used as fertilizer in farm
C. Beddings and Utilities per cycle				
a) Amount of beddings (kg)	6,250.0	160.0	75.0	125.0
b) Water consumption (L)	61,600	2,900	2,200	9,500
c) Power and lighting (kWh)	647.0	136.9	177.8	145.2

2.3) Impact assessment

This study focused on the environmental impact related to climate change characterized by Global Warming Potential (GWP). This term is quite familiar already to both specialist and non-specialist groups. The relevant gases included in the analysis are carbon dioxide, methane, and nitrous oxide, which are discussed by the Environmental Protection Agency (EPA) [28]. Firstly, carbon dioxide (CO_2) enters the atmosphere through burning fossil fuels, solid waste, trees and wood products, and also as a result of certain chemical reactions. Secondly, methane (CH_4) is emitted during the production and transport of coal, natural gas, and oil. CH_4 emissions can also be generated from livestock and other agricultural practices as well as the decay of organic waste in municipal solid waste landfills. One kilogram of CH_4 has 25 GWP versus a kilo of carbon dioxide. Lastly, nitrous oxide (N_2O) is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste. One kilogram of N_2O has 298 GWP versus a kilo of CO_2.

To generate the GHGs of feeds and manure from GLEAM-i, the Philippine setting and type of production system were selected. The feed formulation, manure management and operational parameters on mortality rates and slaughter weight were indicated. Please refer to Supplementary Material (SM) 1 for components breakdown.

Presented in Table 3 is the summary of GHGs of the 4 systems for feed, manure, utilities and beddings with their respective data references.

2.4) Interpretation

The resulting environmental impacts of the 4 systems were rationalized in terms of relative contribution to their GWPs. They were also evaluated versus the average impacts of systems in countries within the East Asian region. Presented in SM 1 is summary of 4 systems and the included countries for benchmarking. The comparison and contrasts further assessed the 4 system's current perfor-mance. To complete the LCA process, areas for improvements were identified. Thereafter, opportunities for improvements or possible action plans were proposed to mitigate the environmental impacts.

Results and discussion

1) Life cycle inventory

The annual inventory was established by multiplying each input with the equivalent number of cycles per year. Presented in Table 4. is the summary of the annual life cycle inventory and their environmental impacts per system. For comparable analysis, the equivalent GWPs were established based on a functional unit of 1 kg CW per system.

Table 3 GHG components of feeds and feeding profile, manure management, utilities and beddings of the 4 systems

Inputs	Unit	CO_2	CH_4 x 10^{-3}	N_2O x 10^{-3}	Reference
A. Feeds					
System A	kg CW	3.84		511.59	Processed by authors in GLEAM-i [15]
System B	kg CW	2.23		372.24	
System C	kg CW	2.50		1,907.11	
System D	kg CW	3.39		1,333.85	
B. Manure					
System A	kg CW		60.32	255.48	
System B	kg CW		117.39	341.01	
System C	kg CW		580.45	4,083.55	
System D	kg CW		284.12	3,326.09	
C. Diesel fuel	L	2.35	0.07	0.33	[29]
D. Gas fuel	L	2.32	0.03	0.03	[29]
E. Water	m^3	0.87	-	-	[30]
F. Electricity	kWh	0.72	-	-	[31]
G. Bedding	kg	0.98	6.60	10.43	[29]

Table 4 Annual life cycle inventory and environmental impacts per system

Inputs	Unit	Quantity	GWP in kg CO_2-eq unit^{-1}				GWP in kg CO_2-eq kg^{-1} CW
			CO_2	CH_4	N_2O	Total	
A: Intensive broiler with 7.5 cycles							
Diesel	L	562.50	1,320.75	0.04	0.18	1,320.97	0.01
Gasoline	L	-	-	-	-	-	
Water	m^3	507.60	441.61	-	-	441.61	0.00
Electricity	kWh	4,852.50	3,498.65	-	-	3,498.65	0.02
Bedding	kg	46,875.00	45,703.13	309.38	488.91	46,501.41	0.30
Feed	kg CW	157,140.00	603,413.05	-	80,391.81	683,804.86	4.35
Manure	kg CW	157,140.00	-	9,478.99	40,145.55	49,624.55	0.32
Total			654,377.19	9,788.41	121,026.46	785,192.05	5.00
B: Small scale broiler with organic feeds with 5 cycles							
Diesel	L	53.00	124.44	0.00	0.02	124.46	0.18
Gasoline	L	-	-	-	-	-	
Water	m^3	13.00	11.31	-	-	11.31	0.02
Electricity	kWh	684.55	493.56	-	-	493.56	0.72
Bedding	kg	800.00	780.00	5.28	8.34	793.62	1.16
Feed	kg CW	684.00	1,528.25	-	254.61	1,782.86	2.61
Manure	kg CW	684.00	-	80.29	233.25	313.54	0.46
Total			2,937.57	85.58	496.22	3,519.37	5.15
C: Backyard chicken with organic feeds with 3 cycles							
Diesel	L	36.00	84.53	0.00	0.01	84.54	0.54
Gasoline	L	-	-	-	-	-	
Water	m^3	6.60	5.74	-	-	5.74	0.04
Electricity	kWh	533.40	384.58	-	-	384.58	2.45
Bedding	kg	225.00	219.38	1.49	2.35	223.21	1.42
Feed	kg CW	157.19	393.21	-	299.79	692.99	4.41
Manure	kg CW	157.19	-	91.24	641.91	733.15	4.66
Total			1,087.43	92.73	944.06	2,124.22	13.51
D: Backyard chicken with commercial feeds with 3 cycles							
Diesel	L	33.06	77.62	0.00	0.01	77.64	0.13
Gasoline	L	40.50	93.92	0.00	0.00	93.92	0.15
Water	m^3	28.50	24.80	-	-	24.80	0.04
Electricity	kWh	435.60	314.07	-	-	314.07	0.52
Bedding	kg	375.00	365.63	2.48	3.91	372.01	0.61
Feed	kg CW	607.05	2,060.04	-	809.71	2,869.76	4.73
Manure	kg CW	607.05	-	172.48	2,019.10	2,191.58	3.61
Total			2,936.08	174.96	2,832.74	5,943.77	9.79

Among the 4 systems, A has the lowest GWP of 5.0 kg CO_2-eq kg^{-1} CW, followed by B: 5.15 CO_2-eq kg^{-1} CW, D: 9.79 CO_2-eq kg^{-1} CW; and C: 13.51 CO_2-eq kg^{-1} CW. To have a comparable evaluation of the respective inputs, their relative contributions were established and shown in Figure 2 for each system.

For system A, feeds (CO_2 and N_2O) is the GWP driver at 87.1%, which concurs with other LCA studies involving intensive broiler chicken production [5–9]. Similarly, in system B, feeds (50.7%) is the driver followed by beddings (22.6%). It is noteworthy that its GWP from feeds is very much lower than A since it uses locally sourced alternative feeds. However, it is compensated by the GWP of bedding given that its birds per cycle in system B is very low that facilitated a higher density of bird per m^2. For broiler systems A and B, manure (CH_4 and N_2O) were not that high since both systems used manure collection in confined beddings. For backyard systems C and D, feeds and manure are the drivers. In terms of feeds, D has higher GWP (48.3%) than C (32.6%) since it utilizes commercial feeds while C uses locally sourced alternatives. In contrast to A and B, systems C and D posted higher GWP from manure with 34.5% and 36.9% respectively, since both have free ranging activities that spread the manure to open space.

For small-scale or backyard systems, the results in B, C and D concurs with past studies [7, 31]. Feeds remains as large contributor to GWP. It is also worth noting that GWP for electricity is significant only to the B, C and D since they have lesser number of birds per cycle. Furthermore, the LCA results in this study confirm that more environmental burdens on organic, small scale and free range operations due to longer production cycle and lower yield versus conventional systems.

2) Comparative GWP performance

For comparative performance analysis using GLEAM-i per country averages [15], the 4 systems' GWPs were compared accordingly to the Philippine (PH) average and among countries with the same topographical conditions such as Indonesia (ID), Malaysia (MY), Thailand (TH). As shown in Figure 3, GWP of A is slightly higher versus PH's average of 4.57 CO_2-eq kg^{-1} CW and ID's 4.92 CO_2-eq kg^{-1} CW. However, it is slightly lower than MY's 5.97 CO_2-eq kg^{-1} CW and TH's 5.08 CO_2-eq kg^{-1} CW. System A's performance is quite satisfactory within the region. However, it is way higher if compared to Eastern Europe's 2.8 CO_2-eq kg^{-1} CW and North America's 3.03 CO_2-eq kg^{-1} CW. This can be associated with the sourcing of feeds raw materials that requires long handling and transportation to arrive in Philippine feed mill companies for further processing. Thereby, a key improvement driver for intensive broiler farm is to explore comparable alternative and locally sourced feed ingredients to mitigate impacts from use of fuel and other utilities across the supply chain in feeds production. System B is higher than PH, ID and TH but better than MY.

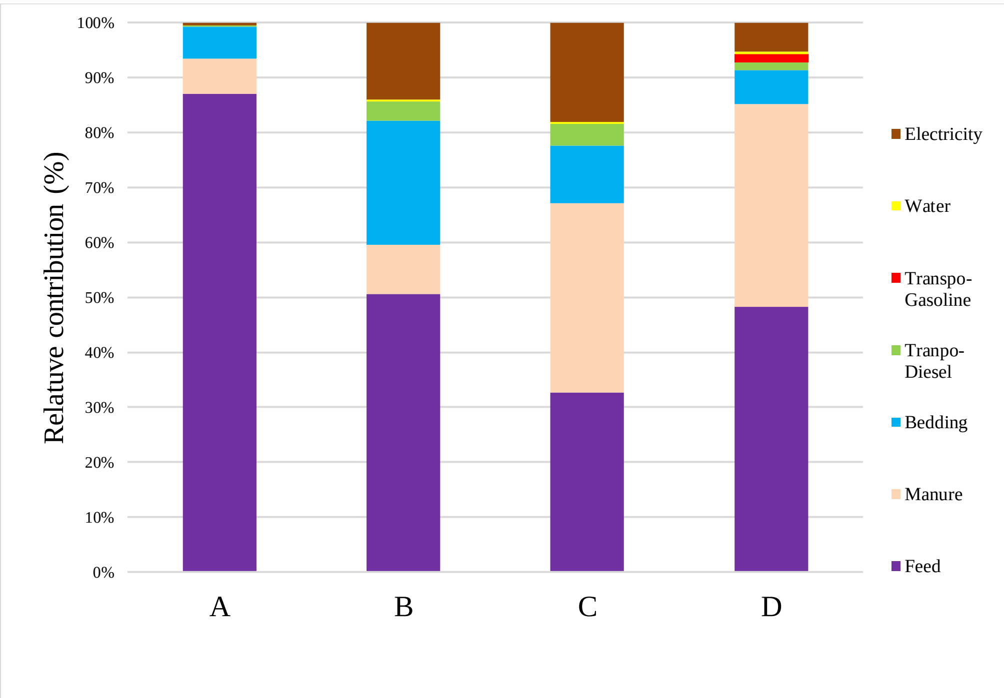

Figure 2 Relative contribution (%) of GHG emission per system.

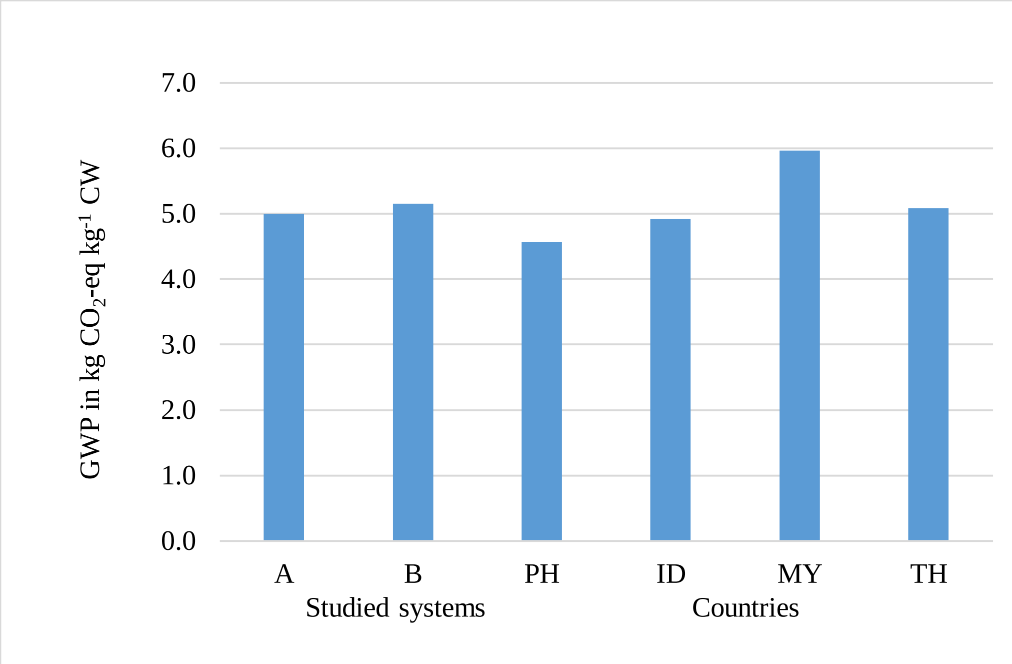

Figure 3 Comparative GWP performance among broiler systems.

At this time, the GLEAM-i data does not include emissions from energy usage for backyard systems. Comparison can be done with feed and manure only, which anyway are the major drivers. The resulting GWP net of energy for C is 9.1 CO_2-eq kg^{-1} CW while 8.3 CO_2-eq kg^{-1} CW for D. As shown in Figure 4, both are higher that PH's average of 5.16 CO_2-eq kg^{-1} CW. Versus neighboring countries, it is still much higher than MY's 5.95 CO_2-eq kg^{-1} CW, TH's 5.37 CO_2-eq kg^{-1} CW and ID's 5.03 CO_2-eq kg^{-1} CW. The management of feed and manure are indicative areas for improvement for C and D.

3) Areas and opportunities for improvement

Presented in Table 5 are the areas for improvement of the 4 systems and possible action plans as opportunities to improve and mitigate their respective GWPs.

4) Contribution to consumption and production patterns

In food systems, consumption and production are interrelated since they both impact each another. The knowledge and focus on GWP can facilitate well-established GWP indicators that can help in shaping production and consumption patterns. Producers can embark on conscious efforts in rationalizing their production systems in terms of inputs, activities and outputs. Mitigation can be done in improving operational efficiencies while lessening environmental impacts. As a metric, producers can indicate the GWP of their products on the labels in the context of transparency. Moreover, this can also be a competitive advantage showing why their product is better or environmentally sound over the others in the market. In return, the consumers have access to information on GWP, which makes them well-informed and empowered. If a healthy and eco-conscious consumer has to choose among the 4 systems, the best choice would be the chicken meat from system B since it is organic with relatively low GWP impact. Though other factors in purchase decision may prevail, consumers are provided with the awareness and ability in making sustainable choices. The active participation from both producers and consumers can have a long-term effect in protecting the environment.

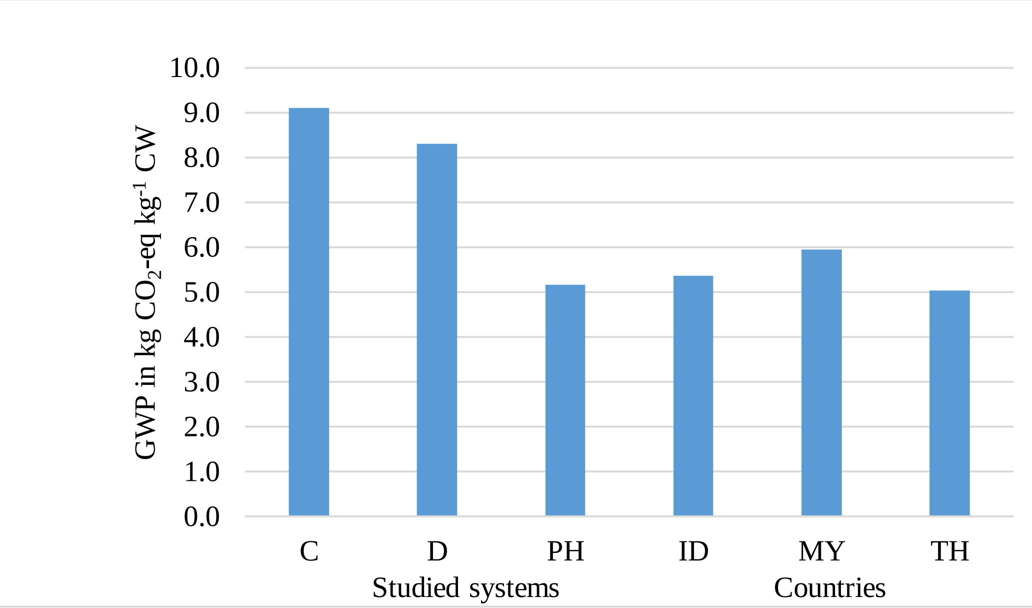

Figure 4 Comparative GWP Performance among backyard systems.

Table 5 Areas and opportunities for improvement in per system

System	**A**	**B**	**C**	**D**
GWP in CO_2-eq Kg^{-1} CW	5.00	5.15	13.51	9.79
Strengths	• Low GWP versus studied systems, close to PH and ID average, better than MY and TH • Economies of scale	• Relatively low GWP versus other small-scale systems • Utilizes locally sourced feed ingredients	• Utilizes organic and locally sourced feed ingredients • Promotes natural farming and free-ranging activities	• Promotes free-ranging activities
Areas for improvement	• High dependence on imported feed ingredients	• Low yield in terms of count	• High GWP versus PH and other countries • Low yield in terms of count and CW • High GWP from manure	• High GWP versus PH and other countries • Use of commercial feeds • Low yield in terms of count • High GWP from manure
Possible action plans	• Use of alternative or locally sourced feed ingredients	• Increase the number of birds per batch	• Increase the number of birds per batch • Increase CW • Improve manure management	• Use of alternative or locally sourced feed ingredients • Increase the number of birds per batch • Improve manure management

Conclusion

This study demonstrated environmental impact evaluation of 4 chicken production systems, namely A: intensive broiler production, B: broiler with organic feed mix, C: backyard with organic feed mix and D: backyard with commercial feeds. Using cradle-to-gate LCA methodology and GLEAM-i system, GHG emissions were identified, quantified and established based on the respective activities, inputs and outputs. The GWPs were expressed in functional unit of 1 kg carcass weight (kg CO_2-eq kg^{-1} CW). System A (5.0 CO_2-eq kg^{-1} CW) has the lowest GWP, followed by B (5.15 CO_2-eq kg^{-1} CW). The other systems with backyard chickens and free ranging activities, C (13.51 CO_2-eq kg^{-1} CW) and D (9.79 CO_2-eq kg^{-1} CW) have high GWP due to longer feeding duration, low production yield and manure spread compared to broiler systems. As part of LCA, improvement opportunities were identified to mitigate the environmental impacts. System A can be further improved by using locally sourced alter-native for feed ingredients; B and C by increasing production yield to maximize the fixed inputs; and D by using locally sourced feed alternatives and increasing production yield. Using GWP as a simple and workable metric for chicken production and consumption can be helpful to both producers and consumers. For producers, the GWP indicator can improve their operations, as well as, establish transparency and competitive advantage. While for consumers, it can make them well-informed and empowered in making sustainable choices and purchases. This can have a long-term effect with the active participation from both producers, consumers and other groups in protecting the environment. The information is available and can be presented for the understanding for both specialist and non-specialist users. This study can help researchers, policymakers, producers and consumers in appreciating the importance of environmental protection criteria. Furthermore, this can also be used as reference by other sectors in livestock or other food-related industries.

Future researches

Future researches should consider the limitations of this study in order to advance the evaluation of GWP as environment protection indicator. Other farms with similar or entirely different system can be considered to strengthen the evaluation. For other applications, studies may consider the varying protein profile of each breed, which can be expressed in GWP per kg protein. This can facilitate the comparison to other meats and protein sources if focus is on nutritive value. Moreover, effective dissemination on LCA among producers and communication strategies among consumers on GWP can be further studied for practical implementation in the Philippines and other countries.

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