



Reduction of Greenhouse Gas Emissions of *Azolla pinnata* Inclusion in Backyard Chicken Production

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ABSTRACT

Backyard chicken production is an integral part among rural families in the tropics like the Philippines. However, it has been declining as it continues to suffer low productivity with its small-scale operations. Among its production inputs, feeds remain to be the top cost driver, as well as the top contributor to greenhouse gas (GHG) emissions that result in global warming potential (GWP). In a prior experiment, 50% inclusion of *Azolla Pinna* was recommended in feed ration due to its favourable and comparable growth performance of Dominant DZ backyard chickens. Hence, this study further evaluated the inclusion in terms of environmental performance. The 50% inclusion resulted in reductions of CO₂ by 35%, N₂O by 22.32%, and CH₄ by 4.74%. The gross effect of this reduction of conventional feeds is a climate change mitigation equivalent 28.47% of GWP kg CO₂ -eq./1,000 birds. The potential impacts indicate that *Azolla Pinnata* can be a cost-effective and sustainable feedstuff in backyard chicken rearing system especially that it requires simple propagation method. The environmental impacts and savings can encourage more livelihood activities in rural.

INTRODUCTION

Backyard Chicken Production

Despite the soaring modernization of commercial poultry production in the global arena, backyard chicken production continues to be a significant activity in the rural and peri-urban areas (Padhi 2016). In this set-up, the backyard chickens, which are usually indigenous, native or improved breed, are typically housed in simple night shelters with limited management and disease prevention measures. They are fed a mixture of household food waste and second-grade crops and are supplemented scavenging for opportunistic food sources such as insects and food scraps. This backyard production is traditionally family-based in small scale and is estimated to contribute 4% of total poultry meat production and 14% of total eggs production worldwide (MacLeod et al. 2013). For small-scale farmers in developing countries, the family-based poultry represents one of the few opportunities for saving, investment and security against risk. Though it is rarely the sole means of livelihood, it is integrated and complementary to farming activities. It can provide

additional income from the sale of birds and eggs, as well as, accessibility to valuable source of protein in the diet (Thieme et al. 2014). However, backyard chicken production has been declining in most countries. Its ability to sustain and achieve the optimal solution to food and nutrition security can only be achieved if constraints, such as inherent low production, diseases, fluctuation in feed prices and access to veterinary services, are properly addressed (Wong et al. 2017).

Just like most rural areas, backyard chicken production in the Philippines is popular. It has been an integral part of the farming systems as a source of chicken meat and eggs. By definition, backyard production comprises of 100 birds of native or improved breeds that are raised primarily for their own consumption in a free-range system of management, which allow birds to forage and look for their food (Sison 2014). The produce of indigenous chicken has been perceived and preferred over the commercial broiler chicken because of taste, leanness and colour, which are more suitable for popular Filipino dishes. With their limited supply, both meat and eggs are priced more than twice the commercial production.

The top producing provinces in the country are Negros Occidental, Iloilo, Bukidnon, Davao del Sur, and Cebu. As of 2016, the backyard operation with native chicken inventory registered at 78.4M in 2016, native breed accounts 44.7% of total chicken, a significant decline from 54.7% in 2001 (PSA 2018). The approximately 20% decline for backyard production can be attributed to the lack of attention and focus given there is little to gain from a very small production base. The decline may continue to progress as the backyard production continue to suffer low productivity and high mortality rates with the limited of technical know-how and usage of optimal resources and inputs. Moreover, technology improvements are not that welcomed with the limited capital and other resources, and adoption disposition (Chang 2007).

Backyard chickens need essential nutrients such as carbohydrates, proteins, fats and oils, minerals, vitamins, and water to survive, grow, and reproduce. To have a consistent and stable marketable weight, some farms used commercial feeds for feeding to complement the forage and free-range activities of the birds. However, the use of commercial feeds increase the cost of production, thereby, supplemental feeding is more economical (Mananghaya 2017).

In terms of duration, feeding is around 90 days to achieve the taste and leanness of native chicken. This means longer feeding period for backyard chicken to achieve 0.7-1.1 kilo weight in ninety days, versus broiler chicken of 1-1.5 kilo over 28 days (Jaturasitha et al. 2002, Roxas 2000).

Azolla Pinnata Feedstuff

In any poultry production system, the highest cost driver is feeds, which accounts for about approximately 50 to 70%. The feed can go as high as 75% of the total cost of production in view of commercial feeds, being the major portion of the variable costs. (Dozier et al. 2008) In the Philippines, the price of commercial feeds will continue to rise. Most of the ingredients are imported such as soybean meal, which is the primary protein source. Various studies have explored the different alternative protein feedstuffs that are abundant in the tropics. One of the promising alternative forages is *Azolla Pinnata*. It is a floating fern belonging to the family of Azollaceae. The fixation and assimilation of atmospheric nitrogen are generated when it hosts the blue-green algae, *Anabaena azollae* symbiotically. Hence, it provides the carbon source and favourable environment for the growth and development of the algae (Rascio & La Rocca 2008). This unique symbiotic relationship makes *Azolla*, an effective and economical plant with high protein content. It has rich nutritive value, which includes proteins, essential amino acids, vitamins (vitamin A, vitamin B12 and beta-carotene),

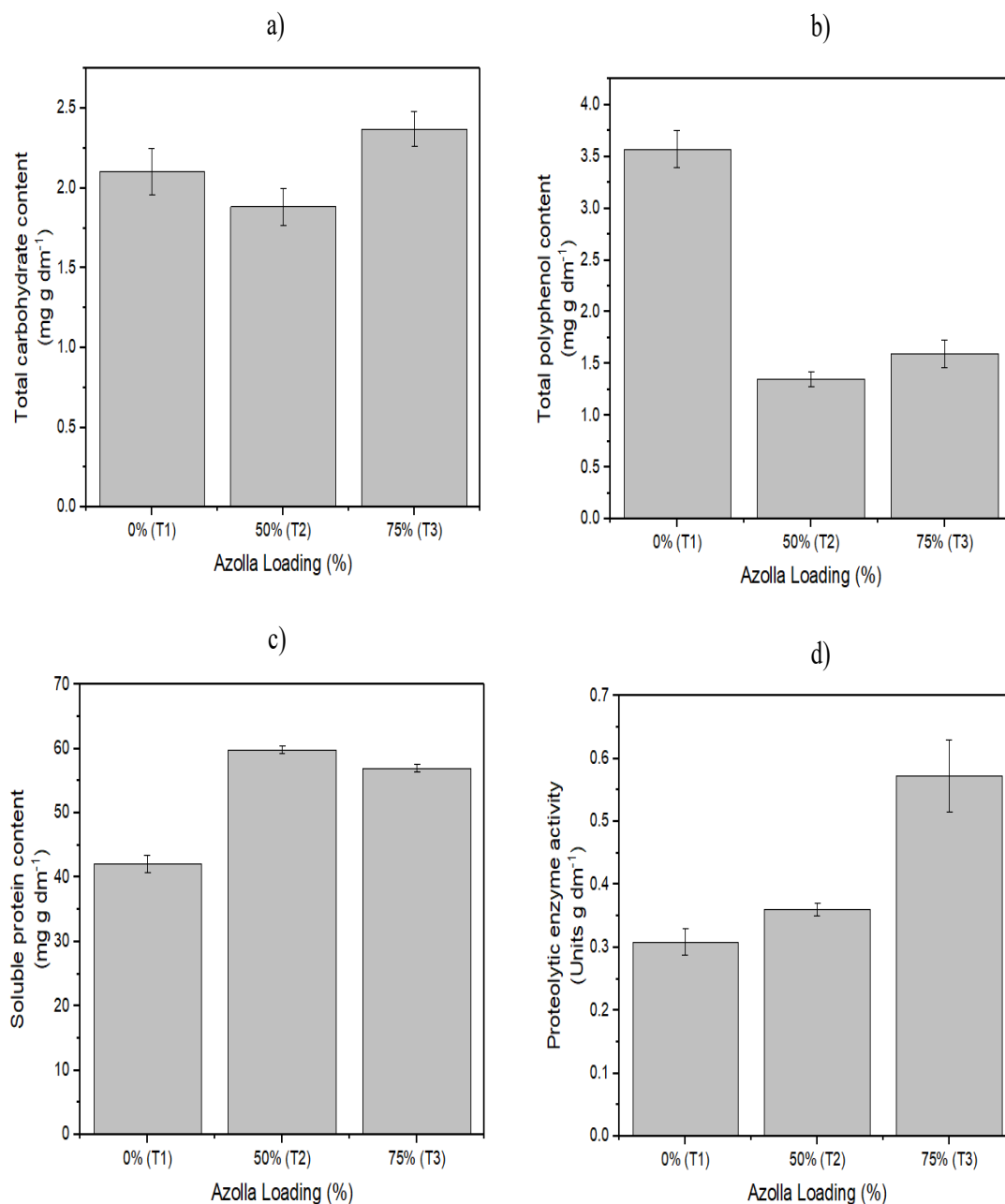
growth promoter intermediaries and minerals like calcium, phosphorous, potassium, ferrous, copper, magnesium etc. It contains 25 to 35 % protein, 10 to 15 % minerals and 7-10% amino acids, bio-active substances and bio-polymers. Its nutrient composition makes it a highly efficient and effective feed for livestock, which can be easily digested, with its high protein and low lignin content (Pillai et al. 2005). In Nigeria, the effect of incorporating graded levels of *Azolla* meal (AZM) in diets of growing pullets was investigated. Particular reference was given to growth, haematology and subsequent laying performance, among 2-week old Nera brown pullets. The results demonstrated a benefit from AZM at a low level of supplementation and up to 15% AZM can be incorporated in diets of growing pullets without jeopardizing the health and subsequent laying performance (Alalade et al. 2007). In another research, the impact of feeding restricted diets supplemented with free fresh *Azolla* (as a good source of crude protein and metabolizable energy, and extra essential nutrients as vitamins and minerals) on performance and economic efficiency of Fayoumi growing chicks was evaluated in Egypt. It was concluded that free fresh *Azolla* could be compensated the restriction diet up to 15% without any counterproductive effects on the performance and edible parts (carcass and internal organs) of Fayoumi growing chicks until marketing age. Moreover, the Fayoumi chicks on the 45% restricted diet, plus free fresh *azolla* achieved the best feed conversion rate and economic efficiency (Namra et al. 2010).

Case Study in the Philippines

In an experiment of the authors of the growth performance, a Dominant CZ Chicken supplemented with AZM was very promising. It was tested on backyard rearing system to investigate how it can be incorporated as an alternative feeds in a farm with backyard rearing system with a tropical climate in Lamacan, Argao in Cebu Province, Region VII, Philippines. The rations were based on an organic farm that campaigned cutting down commercial feeds by at least 50% and looking at almost 100% non-inclusion of commercial feeds in their feeding (PinoyBisnis.com 2010). 27-day old Dominant CZ chicks were used in this study for 90 days. They were randomly grouped to Treatment 1 (T1): control group with 100% commercial feeds, Treatment 2 (T2): the ration with 50% commercial feeds and 50% *Azolla*; and Treatment 3 (T3): ration with 25% commercial feeds and 75% *Azolla*. The standard management practices, rearing and environmental conditions were the same for all treatments. Feeding was provided in ad libitum during the booster stage. While during the starter and grower stages, feeding followed the feed intake guide used in the farm. The results showed that T2 and T3 have satisfactory performance versus T1 since

they were able to achieve the marketable weight of 1000 grams in 90 days. The average weight gain of T2 was 1,094.6 grams, which is just 8.2% lower than the T1 at 1,194.4, while T3 was 1,081.2 or 9.4% versus T1. The details in growth performance evaluation can be found in Table 1. A separate

meat chemical composition analysis (Siacor 2019) on total carbohydrate, polyphenol, soluble protein, and proteolytic enzyme activity was done with results in Fig. 1. The results on growth performance and meat quality of the chickens fed with 50% AZM were favourable.



Source: (Siacor,2019)

Fig. 1: Meat Chemical Composition with various Azolla Loading.

a) Total carbohydrate b) polyphenol c) soluble protein d) proteolytic enzyme activity of the chicken carcass at varying levels of Azolla loading in the chicken feed (values represent an average for three replicates; error bars represent standard deviation)

Table 1: Growth Performance of CZ Chickens at different feeding stages

Attributes	T0 control	T1 50% <i>Azolla</i>	T2 75% <i>Azolla</i>	Mean	SEM
CUMMULATIVE WEIGHT (g)					
Initial	49.62	50.51	50.59	50.23	1.12
Booster	231.21	182.89	181.05	199.05	7.83
Starter	826.57	754.09	686.06	758.25	17.84
Grower	1,244.03	1,145.09	1,131.74	1,175.23	20.75
WEIGHT GAIN (g)					
Booster	181.59 ^a	132.38 ^a	130.46 ^a	148.82	7.72
Starter	595.36 ^a	571.20 ^b	505.01 ^{ab}	559.20	12.86
Grower	417.47	391.00	445.68	416.98	11.76
Total	1,194.41 ^a	1,094.58 ^a	1,081.15 ^a	1,125.00	20.85
Ave. Daily	13.27	12.16	12.01	12.50	0.23
FEED INTAKE (g)					
Booster	320.25	310.07	295.19	308.50	8.18
Starter	1,433.01	1,471.15	1,463.23	1,455.80	7.68
Grower	2,190.02	2,185.31	2,170.43	2,181.92	7.80
Total	3,943.28	3,966.53	3,928.85	3,946.22	18.86
Ave daily	43.81	44.07	43.65	43.85	0.21
CONVERSION RATIO					
Booster	1.76	2.34	2.26	2.27	0.11
Starter	2.41 ^a	2.58 ^b	2.90 ^{ab}	2.64	0.06
Grower	5.25	5.59	4.87	5.34	0.16
Total	3.30 ^a	3.62 ^a	3.63 ^a	3.54	0.06

Mean values within a row with superscripts differ significantly ($p < 0.05$); Source: (Authors)

Environmental Impacts

One of the environmental concerns in any producing industry is global warming. It is the average increase in the temperature of the atmosphere near the Earth's surface and in the troposphere, which can contribute to changes in global climate patterns. Global warming can have many different causes, but it is most commonly associated with human interference, specifically the release of excessive amounts of greenhouse gases such as carbon dioxide (CO₂), methane (CH₄), water vapour, and fluorinated gases earth (EPA 2017). Based on World Resources Institute Climate Analysis Indicators Tool, the Philippines' total GHG emissions are at 57.6 million metric tons of carbon dioxide equivalent (Mt CO₂e), 0.33% of global GHG emissions. This was dominated by the energy sector (54%), followed by agriculture (33%), industrial processes (IP) (8%), and waste (7%). Between 1990-2012, total GHG increased by 54 MtCO₂e or an equivalent of 53% over the period and an annual change of 2.1%. These were driven by energy (3.4%), agriculture (1.5%), IP (7.1%), waste (2.1%), and land use change and forestry (-12.4%) (USAID 2016). In response

to the increasing GHG, the Philippine Climate Change Commission (CCC) (Climate Change Commission 2011) formulated the 2010-2028 National Framework Strategy on Climate Change which identified a long-term mitigation objective of facilitating the transition towards low GHG emissions for sustainable development. CCC outlined the national climate change action plan in 2011. For agriculture, it articulated the following activities: enhance site-specific knowledge on the vulnerability of agriculture and fisheries to the impacts of climate change; conduct researches and disseminate knowledge and technologies on CC adaptation to reduce vulnerability of the sector to climate change; and establish knowledge management on climate change information for agriculture. Moreover, the country committed to reducing its GHG emissions by 70% by 2030 compared to a business-as-usual scenario through mitigation measures in the energy, transport, waste, forestry, and industry sectors.

Aligned to climate change initiatives, this research aims to answer the following questions: What is the GWP impact of the studied backyard system? and How much GWP impact is reduced with the inclusion of *Azolla Pinnata* in the ration?

With the formulated questions, this study aimed to evaluate the potential GWP reduction with the inclusion of AZM.

MATERIALS AND METHODS

Life Cycle Assessment (LCA)

This study utilizes the Life Cycle Assessment (LCA), an environmental management tool to evaluate a certain product or process in view of assessing and optimizing the quality of a system, in terms of environmental impacts over its entire life cycle. The concept was introduced by SETAC (Society of Environmental Toxicology and Chemistry) and has become a credible technique in many sustainability and environmental assessment endeavours among policymakers, manufacturers and consumers in planning and decision-making activities (Jensen 2008).

Impact Categories

The study focuses on Climate Change, the Global Warming Potential based on TRACI 2.1 (the Tool for the Reduction and Assessment of Chemical and other Environmental Impacts). TRACI 2.1 utilizes global warming potentials (GWPs) for the calculation of the potency of greenhouse gases relative to CO₂, expressed as kgCO₂/equivalent (Bare 2012). The relevant gases in the analysis are carbon dioxide, methane and nitrous oxide, which are discussed by (EPA 2017) to be as follows.

Carbon dioxide (CO₂) enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and wood products, and also as a result of certain chemical reactions. Carbon dioxide is removed from the atmosphere (or “sequestered”) when it is absorbed by plants as part of the biological carbon cycle.

Methane (CH₄) is emitted during the production and transport of coal, natural gas, and oil. CH₄ 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 CH₄ has 25 GWP versus a

kilo of carbon dioxide.

Nitrous oxide (N₂O) is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste. One kilogram of N₂O has 298 GWP versus a kilo of carbon dioxide

Data Collection

The data on the material flow included the various inputs and outputs within the system boundaries of the scope of the study farm. The relevant data were collected from interviews of the farm owner, caretaker and observations during the conduct of the feeding trial. The collected data were then classified and established based on their equivalence per gas category. Presented in Table 2 is the summary of GHG factors.

The databases on GHG emissions on transportation, agricultural wastes and biomasses were based from (Engineering Tool Box 2009, EPA 2017). For utilities, from the equivalent carbon footprint of water (Griffiths-Sattenspiel & Wilson 2009) while electricity from Philippine’s national grid emission factor. (DOE, 2017) Lastly, for feed and manure, GLEAM-interactive (GLEAM-i) (FAO 2017) was used. The parameters on the production system, feed formulation, manure management and operational parameters on mortality rates, slaughter weight and manure management were inputted in GLEAM-i to generate the corresponding GHGs of the studied farm. The same system and process were done in establishing the corresponding GHG of feeds and manure for AZM inclusions.

RESULTS AND DISCUSSION

Material Flow Analysis of the Backyard Chicken Farm

The boundary and material analyses are shown in Fig. 2. The farm raises Dominant CZ breed on backyard free-range rearing system. One production cycle is composed of 200 birds in 90 days with 5% average mortality. The DOCs, weighing an average of 50 grams each, are transported to the farm using a multi-cab from a hatchery in a nearby town,

Table 2: GHG Emission Factors of different inputs used in the Backyard Chicken Farm.

Inputs	Unit	CO ₂	CH ₄	N ₂ O
		kg/Unit	g/Unit	g/Unit
Transpo-Delivery	L	2.3480	0.0026	0.0011
Transpo-Motorcycle	L	2.3190	0.0011	0.0001
Electricity	kWh	0.6030		
Water	m ³	0.8700		
Bedding	kg	0.9750	0.2640	0.0350
Feed	kg CW	1.6853	-	4.4760
Manure	kg CW	-	11.3649	11.1614

37.1 km in distance. To make sure their health and survival, DOCs stay in an area with brooding lights that facilitate the required temperature and humidity. The corresponding required electricity to maintain this artificial brooding is 1 watt per bird. Aside from catching the litters of DOCS, the rice hull bedding also provides the heat necessary for brooding. Approximately 125 kg of rice hulls is used for both brooding and rearing stages.

After 28 days, the birds are allowed to range. The typical area estimated for free-ranging is 1 sqm. per bird. One caretaker is in charge of maintaining the cleanliness of the barn and farm, feeding the birds and pasturing them. The caretaker went to the ranging area twice a day, morning and afternoon for feeding and pasturing. He rode a motorcycle along a distance of approximately 1.5 km from the owner's place to the farm.

In a 90 day-cycle, one bird can consume 3.9 kilos of commercial feeds, which comprises 8.4% starter feeds given over 28 days; 37.8% starter over 35 days; and 53.8% grower 53.8% over 27 days. The conventional feeds are commercially available in the market, which is approximately 3 km from the owner's place. The required feeds are procured

every two weeks and are stored at the owner's place. Only the required amount per feeding is brought to the farm. To ensure health and safety, basic recommended vaccines are also provided to the growing chicks.

In terms of water consumption, one bird drinks 0.5 litres per day or a total of 45 litres over the cycle. Minimal water is used in cleaning and up-keeping the barn and farm. Both water and electricity are locally supplied by respective service providers. The average utilities in a cycle are 9.5 m³ for water and 145.2 kWh for electricity.

At the end of the cycle, the birds have an average live weight of 1.5 kg. They are usually sold live but sometimes are slaughtered at the farm and sold as roasted chicken. The average dressing percentage is 71%, which makes the dressed chicken equivalent to approximately 1 kg.

Environmental Impact

Life cycle inventory and GHG emissions of current set-up: The life cycle inventory and GHG emission, as given in Table 3, were quantified based on 1,000 birds or an equivalent of 5 cycles for easier reference and analysis in this study. The current set-up is an equivalent global warming potential of

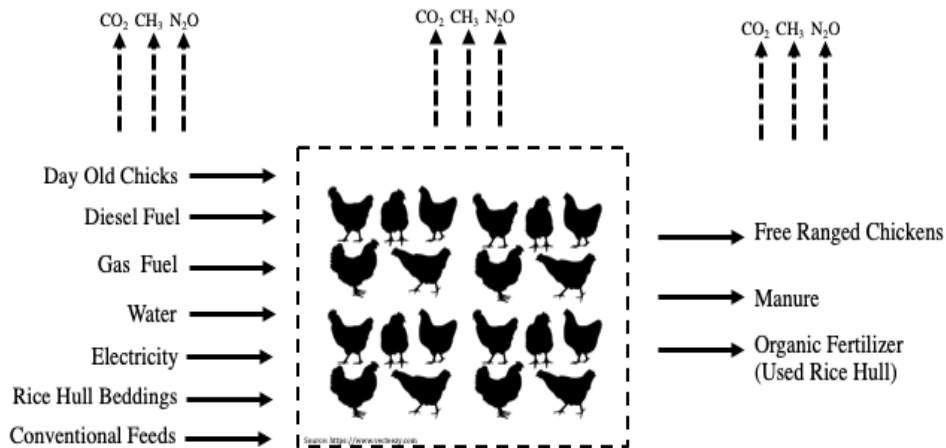


Fig. 2: Gate to gate system boundary of backyard chicken farm.

Table 3: Life Cycle Inventory and GHG Emissions per 1,000 birds of current set-up.

Inputs	Unit	Quantity	GWP in GWP in kg CO ₂ -eq/unit			Total
			CO ₂	CH ₄	N ₂ O	
Tranpo-Diesel	L	55.10	129.375	0.004	0.018	129.396
Tranpo-Gasoline	L	67.50	156.533	0.002	0.002	156.536
Electricity	kWh	726.00	437.778	-	-	437.778
Water	m ³	47.50	41.325	-	-	41.325
Bedding	kg	625.00	609.375	4.125	6.519	620.019
Feed	kg CW	1,011.75	3,433.408	-	1,349.522	4,782.929
Manure	kg CW	1,011.75	-	287.462	3,365.168	3,652.630
Total			4,807.793	291.592	4,721.229	9,820.614

9,820.614 kg CO₂ eq. Among GHG gasses, carbon dioxide contributed the highest at 48.96% followed by nitrogen oxide at 48.07%. Carbon dioxide is generated much from the use of conventional feeds, followed by use of electricity and fuels. As discussed in the inventory analysis, there is limited transportation activities, with most of it coming from the mobility of the caretaker for feeding and pasturing. Also, the use of rice hull beddings is limited to the brooding area since the birds are allowed to range after 28 days. For nitrogen dioxide, it is basically driven by the use of conventional feeds and manure. The methane gas has minimal impact given that it has limited transportation activities, thereby, its major contributor is just manure.

The Gleam-I data does not include emissions from direct and indirect uses for backyard chickens. Thereby, comparison can be done with feed and manure related components only. The farm's 8,345.56 kg CO₂ eq/1,000 birds is much higher than Philippine's baseline average of 5,675.92 and East Asia and Southeast Asia regional average of 6,546.02 kg CO₂ eq/ 1,000 birds. Versus neighbouring countries, it is still much higher with Malaysia's 6,019.91, Thailand's 5,433.10 and Indonesia's 5,089.10.

The high GWP per 1,000 birds in this system can be directly associated with the use of commercial feeds and the yield per cycle. Hence, the area for improvements in this system is to use alternative feeds with lower environmental impact as well as improve the average yield to distribute the impacts of the fixed inputs.

Global warming potential impact of AZM inclusion:

The inclusion of *Azolla Pinnata* has no significant potential adverse effect in global warming potential on various forms as demonstrated on the studies (Kimani et al. 2018) on a rice paddy in Japan; (Xu et al. 2017) on double rice cropping system in southern China; (Jumadi et al. 2014) on the growth of upland Kangkong in silt loam soil in Indonesia. In providing a regular source of the floating fern, the farm uses a 2 sqm improvised water tub, wherein the *Azolla Pinnata* is propagated and harvested daily when needed. With the propagation method and application, there is no quantifiable impact from *Azolla Pinnata* to be considered.

The recommended 50% replacement of commercial feeds cut down the volume of feeds by half. This new feed mix ratio was inputted to the Gleam-I system, which changed the GHG profiles of feed and manure. As given in Table 4, the total GWP decreased to 7,024.83 kg CO₂ eq/1,000 bird. The 50% AZM resulted in a reduction of CO₂ by 35%; N₂O by 22.32%, CH₄ by 4.74%, and total GWP by 28.47%, as shown in Fig. 3.

In terms of relative contribution in Fig. 4, feeds decreased its share by 14.95% while manure increased by 9.3%, beddings by 2.51%, electricity by 1.77% and less than 1% for diesel and gasoline respectively.

Aside from the decrease in GWP, it is worth noting that the reduction in commercial feeds and replacement with AZM will also have a significant effect on production costs. Hence, the 50% AZM inclusion provides both environmental and economic impacts of this studied farm.

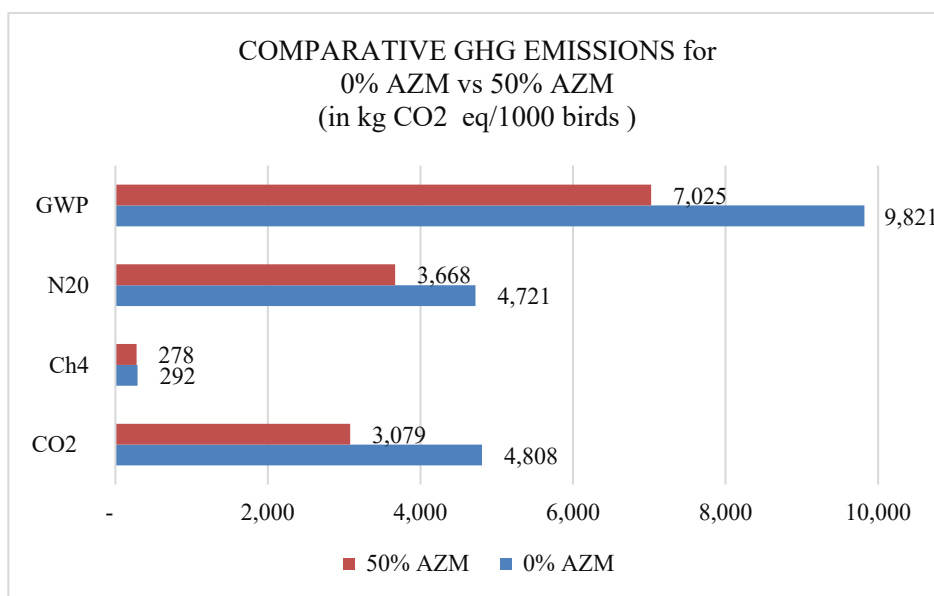


Fig. 3: Comparative GHG emissions for 0% AZM versus 50% AZM.

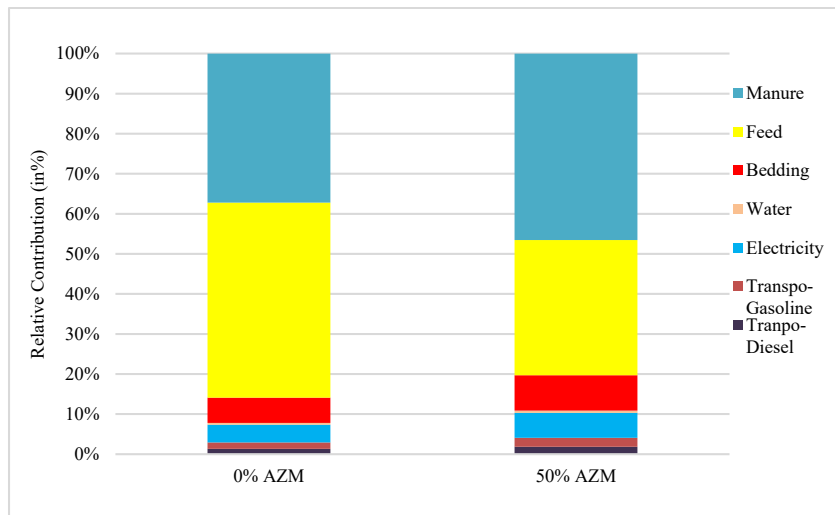


Fig. 4: Relative Contribution of Inputs to GWP.

Table 4: Life Cycle Inventory and GHG Emissions per 1,000 birds with 50% AZM inclusion.

Inputs	Unit	Quantity	GWP in GWP in kg CO ₂ -eq/unit			
			CO ₂	CH ₄	N ₂ O	Total
Tranpo-Diesel	L	55.10	2.3480	0.0001	0.0003	129.3964
Transpo-Gasoline	L	67.50	2.3190	0.0000	0.0000	156.5364
Electricity	kWh	726.00	0.6030	-	-	437.7780
Water	m ³	47.50	0.8700	-	-	41.3250
Bedding	kg	625.00	0.9750	0.0066	0.0104	620.0188
Feed	kg CW	1,011.75	1.6853		0.6585	2,371.3025
Manure	kg CW	1,011.75		0.2704	2.9601	3,268.4761
Total			3,079.491	277.757	3,667.586	7,024.8331

CONCLUSION AND PERSPECTIVES

The studied farm has a GWP impact of 9,820.614 kg CO₂-eq./1,000 birds with its current set-up using the commercial feed to Dominant CZ breed in backyard free-range rearing system. With the recommended inclusion of 50% AZM, GWP reduced to 7,024.83. This showed favourable results since there were reductions of CO₂ by 35%; N₂O by 22.32%, CH₄ by 4.74%. The gross effect of this reduction of conventional feeds is a climate change mitigation equivalent 28.47% of GWP kg CO₂-eq./1,000 birds. The environmental evaluation of AZM showed that the floating fern has favourable benefits, especially in the countryside. Moreover, potential savings can be generated from the 50% decrease in commercial feeds. The impacts indicate that Azolla Pinnata can be a cost-effective and sustainable feedstuff in backyard chicken rearing system especially that it requires simple propagation method. The environmental impact and savings can encourage more livelihood activities in rural.

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