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EXPLORING THE POTENTIAL USE OF ENVIRONMENTAL LIFE CYCLE COSTING (ELCC) FOR SUSTAINABLE POULTRY PRODUCTION IN MALAYSIA

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The agriculture sector is essential for sustainable food production and maintaining socio-economic stability. Throughout the world, this sector continually faces the challenge of remaining profitable while addressing various environmental concerns. Currently, Malaysia is one of the countries that aspire to fulfil the global efforts towards sustainable agriculture. However, the challenge remains to assess the economic cost of environmental emissions generated from these activities. Given this, a study was carried out to evaluate the environmental cost associated with the agricultural sub-sector of poultry production. The study applied the method of life cycle assessment (LCA) to assess the overall environmental impacts. Following this, the approach of life cycle costing (LCC) and environmental life cycle costing (ELCC) was adopted, whereby the results for potential cost increase were assessed. The overall results indicated a potential cost increase of 25.12% if the environmental costs are included in future production costs. To avoid refusal among the producers, the best option is to encourage them to mitigate and reduce emissions before policymakers can implement new policies to impose the cost on the market. It is hoped that the findings in this study will serve as a reference for various methods to assess the environmental cost related to the agricultural sector in Malaysia.

Keywords: poultry production, environmental life cycle costing, emissions mitigation, sustainable production

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INTRODUCTION

Environmental management is the cornerstone of a product's overall sustainability. Currently, various approaches have been developed to assess the ecological impacts of products, ranging from agricultural to industrial applications. One of the popular techniques is life cycle thinking (LCT) (García-Herrero et al., 2022). Since its development, several life cycle approaches have been introduced, including life cycle assessment (LCA), life cycle costing (LCC), and social life cycle assessment (SLCA). These approaches represent a triple pillar empowerment between environmental protection, economic viability, and social considerations. The advancement of the techniques has since observed several improvements made, especially from an economic point of view. These include the new approaches of LCC, which was expanded into environmental life cycle costing (ELCC). This method considers both internal and external costs in its assessment (Rodrigues & da Silva, 2024).

The integration of ELCC within the agricultural framework will provide the opportunity for environmental emissions to be assessed in terms of their impact on the economy. Currently, Malaysia is one of the countries that is progressively moving towards sustainability in agricultural production (MAFI, 2021). As the country progresses towards becoming a high-income nation, the shift in market demand towards a sustainable product reflects the consumer preferences for products with minimal environmental impact (Isa et al., 2021). In view of this, the approach of ELCC can be adopted to assess specific environmental costs of agricultural products or services. There is a need for specific methods to evaluate the cost of emissions based on the local scenarios, including the poultry production sector. This sector has become one of the key economic growth among the smallholders. However, this industry is currently facing several environmental issues that require immediate assessment and proactive actions (Himu & Raihan, 2023). Thus, this study was conducted to assess the prospects of integrating the ELCC technique within the conventional economic cost assessment of the poultry chicken production system.

METHODOLOGY

To identify the important elements required for ELCC, the important steps within the international ISO standards for life cycle assessment (LCA) and life cycle costing (LCC) were first established (ISO 14040, 2006; ISO 14044, 2006). The steps are highlighted as follows:

1. **Goal and Scope Definition:** The steps include identifying the goal and scope for the life cycle assessment (LCA) study, the inventory process required, impact assessment, and interpretation. These steps are vital to ensure that our assessment of the agricultural process is relevant to this industry, particularly related to the environmental impacts and their associated environmental cost.

2. **Life cycle inventory and impact assessment (LCIA):** The inventory on the inputs required for poultry chicken production was obtained from a contract farmer located in the state of Johor, Malaysia. This data includes the amount of raw materials required for chicken production and also the overall costs throughout its production from farm-to-gate. Following this, the environmental impacts using the LCA method were assessed based on ReCiPe midpoint analyses used in the LCA tool software, SimaPro version 9.3 (Pré Sustainabilty B.V).

3. **Life cycle costing (LCC) analysis:** The cost of production of poultry chicken was assessed using the approach of life cycle costing. This includes the assessment of capital expenditure as well as the operational expenditure required per cycle of production season.

4. **Environmental life cycle cost (ELCC) analysis**: Previously, the assessment using eco-cost has been applied to an LCA study for environmental costs (Mano et al., 2017). Therefore, the references used for environmental cost or eco-cost were identified. The eco-cost mid-point table (www.ecocostvalue.com) was used as the main reference for potential cost increases due to environmental emissions (Delft University of Technology, 2024). The data was updated at the latest of the 5th of March 2024. These data were shown in Table 1.

5. **Financial assessment per unit of production:** This study applied the economic analysis method of purchasing power parity (PPP) for the conversion of environmental costs into the local currency unit (LCU). The approach followed a detailed analysis using the PPP-adjusted values as highlighted by Pirmana et al. (2021). The data was based on the conversion values from the analysis by Worldbank (2024). Subsequently, the potential increase in final costs was assessed based on the integration of the steps between LCA, LCC, and ELCC. The analysis was based on per kg of chicken production.

Table 1 – Eco-cost value of selected environmental indicators

No.	Eco-cost Category	Indicators in ReCiPe	Marginal costs in Malaysian Ringgit

			(RM) based on PPP-adjusted values (2024)
1.	Global warming (carbon footprint)	Global warming	RM 0.2865/ kg CO_2 equivalent (GWP 100)
2.	Fine dust	Fine particulate matter formation	RM 86.3661/ kg fine dust PM 2.5 equivalent
3.	Acidification	Terrestrial acidification	RM 21.54/ kg SO_2 equivalent
4.	Eutrophication – freshwater	Freshwater eutrophication	RM 35.45/ kg P equivalent
5.	Ecotoxicity-freshwater	Freshwater ecotoxicity	RM 0.0062/ CTUe
6.	Human toxicity (cancer)	Human carcinogenic toxicity	RM 1981466/ CTUh
7.	Human toxicity (non-cancer)	Human non-carcinogenic toxicity	RM 465214 / CTUh
8.	Photochemical oxidant formation	Ozone formation, human health	RM 13.1811/ kg NOx equivalent
9.	Fossil fuel depletion	Fossil resource scarcity	RM 1.8307/ kg oil

RESULT AND DISCUSSION

The LCA study identified nine environmental impact indicators most relevant to the agricultural sector. These indicators were global warming, freshwater ecotoxicity, human carcinogenic toxicity, human non-carcinogenic toxicity, freshwater eutrophication, ozone formation (human health), fine particulate matter formation, terrestrial acidification, and fossil resource scarcity (Table 1). Table 2 and Table 3 indicate the results from the analysis conducted using the LCA and conversion values to economic cost using the ELCC approach. The results highlighted a potential increase of 25.12% of the overall cost if the environmental cost were to be included as part of the total costs. The amount can be considered substantial considering the industry is currently grappling with price fluctuations on inputs (Wong & Khazali, 2023). This includes the costs of feed, which is mostly imported from other countries.

Table 2- Environmental emissions from poultry production for the eco-cost estimate

Impact category	**Emissions (per kg chicken)**	**Eco-cost in Malaysian Ringgit (RM per kg chicken)**
Global warming	0.76949 kg CO_2 eq	0.22
Fine dust	0.00175 kg $PM_{2.5}$ eq	0.15
Acidification	0.00679 kg SO_2 eq	0.15
Eutrophication–freshwater	0.00032 kg P eq	0.01
Ecotoxicity-freshwater	0.03138 kg 1,4-DCB	0.19
Human toxicity (cancer)	0.03558 kg 1,4-DCB	0.01
Human toxicity (non-cancer)	0.56726 kg 1,4-DCB	0.01
Photochemical oxidant formation	0.00309 kg NOx eq	0.04
Fossil fuel depletion	0.16540 kg oil eq	0.30

Table 3 –Economic indicator using ELCC for poultry production

Items	**Economic indicator**
Production cost (capital + operational)	RM 4.34/ kg chicken
Total eco-cost	RM 1.09/ kg chicken
Total production cost + eco-cost	RM 5.43/ kg chicken
Percentage increment	25.12 %

The implementation of environmental costs will incur potential negative feedback among the agricultural practitioners. There are two ways in which the cost will be absorbed in the market. Firstly, it can be absorbed by producers following the polluter-pays principle, in which those who emit pollution will bear the costs (Zhu, 2023). Due to some conditions, it can be expected that any future costs can also be distributed to the consumers rather than solely being absorbed by the producers. Nevertheless, the best way to move forward is to support the agricultural industry towards greener practices, such as mitigating greenhouse gas and other emissions. In this regard, the technique used in interpreting life cycle impact assessment can be applied to highlight priorities in hotspot identification as sources for environmental mitigation (Castellani et al., 2017). In this study, exploring green and sustainable options for reducing GHG emissions and fossil fuel alternatives should be the main priorities. This included minimizing losses from feed over consumption as well as shifting from fossil fuels to biomass sources.

FUTURE RECOMMENDATIONS

Malaysia has recently developed the Voluntary Carbon Exchange (VCE) (Rahman et al., 2020), which aims to demonstrate the government's commitment to environmental sustainability. Generally, the country has made progress in establishing a carbon pricing system, where the value within the voluntary carbon market has been developed (Bursa Malaysia, 2025). However, the price for other emissions is still not yet established, although certain economic impacts have been estimated and published, such as those related to fine dust (Manan et al., 2018) and acidification (The Sun, 2023). There is a need to integrate and synergize established international methodologies with the local framework to determine areas of improvement. Concurrently, several studies on the other crop-sub subsector, such as rice and oil palm, have carried out a comprehensive environmental assessment of Malaysia’s agricultural sector (Abdul Rahman et al., 2019; Hashim et al., 2018). Therefore, the findings from this study ascertain the need to assess the environmental impacts holistically from the perspective of economic analysis, thus providing the stakeholders with comprehensive information for sustainable policy decisions in the agricultural sector. This will contribute to the government's future green and sustainable initiatives.

CONCLUSION

This study highlights the potential applications of ELCC in the poultry sector in Malaysia. It has brought new highlights to Malaysia’s environmental assessment from the potential life cycle approach, deriving from an economic perspective. The study on poultry chicken production indicated a potential 25.12% increase in the total overall cost. This indicates a substantial increase if the external environmental cost is to be included within the conventional internal assessment of production costs. To alleviate the burden on producers, policy reforms and technological interventions are needed to guide the poultry industry towards a comprehensive sustainability framework.

Essentially, the agricultural producers should be introduced to the new technologies to reduce emissions. These include new approaches to alternative feed sources and biomass-based fuels. In the future, these approaches could be streamlined with government policies on food security and sustainable agricultural production. In the future, a multi-stakeholder engagement will be imperative to the successful implementation of environmental reduction strategies for the country. Given this, the approach of ELCC could be integrated and implemented in other agricultural sub-sectors for a more holistic and sector-wide assessment.

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