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Life Cycle Assessment of Slaughtered Pork Production: A Case Study in Thailand

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ABSTRACT

Pork is a staple food in many cultures worldwide and plays a significant role in global food systems. However, the production of pork is associated with various environmental issues throughout its life cycle. This study employed a life cycle assessment (LCA) to evaluate the environmental impact of slaughtered pork production in Thailand. The system boundaries encompassed pig breeding, pig farming, and slaughtering. The primary focus was on identifying significant contributors to environmental burdens throughout the pork production chain. Three scenarios for pig feed compositions were assessed. The results indicated that pork production generated a total impact of 5.07 kgCO_2-eq on global warming, 1.16E-03 kgP-eq on freshwater eutrophication, 4.69 m^2a-eq on land use, and 4.97 m^3 on water consumption. Pig feed production, particularly maize cultivation, emerged as a hotspot within the life cycle, contributing the highest impact across all categories. According to scenario analysis, the substitution of rice by-products and sorghum in pig feed tended to reduce the magnitude of the impact. Opportunities were suggested to improve the environmental performance of pork production, especially through feed strategies such as substituting high-impact ingredients with more sustainable alternatives and utilizing waste from pig farming and slaughtering.

1. INTRODUCTION

Pork is recognized as one of the important protein sources contributing to global food security. It plays a significant role in various cuisines worldwide, with approximately 116 million tons of pork (11.3 kg per capita) consumed in 2023 (OECD, 2024). In Thailand, consumer demand for pork rose to 1.317 million tons in 2023, a 16.76 percent increase from 1.128 million tons in 2022. It is also exported to neighboring countries such as Hong Kong, Myanmar, and Laos, with an export volume of 1.771 tons in 2023 (Office of Agricultural Economics, 2023). Nonetheless, there has been increasing interest in recent years concerning sustainable food production due to depleting natural resources and environmental effects. Sustainable pork production is a promising practice that can enhance environmental quality, economic benefits, and social responsibility (Öhlund et al., 2017). There are various production factors as well as environmental emissions associated with pork production, such as pig feed, water, fossil fuels, electricity, wastewater, bio-waste, and transportation (Nguyen et al., 2011; McAuliffe et al., 2016; Winkler et al., 2016). These factors may contribute, directly or indirectly, to environmental impacts.

Increased pork demand has driven the expansion of intensive pig farming, causing a wide range of environmental impacts. This includes deforestation for pig pens, feed crops, and infrastructure, leading to habitat loss and biodiversity decline (Long et al., 2021). Various studies suggested that pork production contributes to greenhouse gas emissions occurring at different stages of the product life cycle, such as feed production, manure management, and fuel combustion (Dai et al., 2021; Pazmiño and Ramirez, 2021). In addition, pigs excrete large amounts of manure

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containing organic substances, i.e., nitrogen and phosphorus, which can cause eutrophication as well as pollution in surface water and groundwater (De La Mora-Orozco et al., 2018). The production of pig feed, often based on crops such as soy and corn, requires significant energy inputs for cultivation, processing, and transportation (De Quelen et al., 2021). Pig farming in South America contributes to deforestation due to its heavy reliance on soybean feed (Rajão et al., 2020).

Life Cycle Assessment (LCA), a standardized environmental assessment tool for a product or service based on a life cycle perspective, has been used to holistically assess the environmental impacts of pig farming and pork production. LCA is used extensively to quantify and highlight the significant environmental impacts (or hotspots) of a concerned product at every stage, ranging from raw material acquisition, manufacturing process, use, transportation, and waste management. LCA can be a valuable tool to inform decision-makers toward more sustainable pork production by identifying environmental hotspots, comparing different production systems, and evaluating the potential of new technologies (McAuliffe et al., 2016). In LCA studies concerning pork supply chains, system boundaries are often defined up to either the farm gate or slaughter gate. Among life cycle stages, the cultivation of feed used in pig farming is often identified as a primary contributor to environmental impacts. This is primarily due to its direct association with land use change as well as the intensive use of agrochemicals and fossil fuels (Bava et al., 2017; Dorca-Preda et al., 2021; Zira et al., 2021). Also, manure management can potentially contribute to greenhouse gas emissions and acidification, as suggested by Djekic et al. (2015). Changing feed composition, particularly a decrease in high-impact ingredients such as soybean meal and maize, can mitigate the overall influences of pig feed (Ottosen et al., 2021). Tailoring the nutrient content of the feed to the exact needs of the pig at each stage of growth, or precision feeding, can boost farm profitability and efficiency, and improve the environmental performance of pig feed (Pomar and Remus, 2019). Organic pig farming could be more environmentally beneficial than conventional farming as the environmental effects of organic pork were shown to be 38-80% lower than conventional pork in all impact categories (Zira et al., 2021).

While numerous LCA studies have been conducted on pork production in various regions globally, there remains an existing gap in research concerning the context of Thailand. Moreover, Thailand's reliance on rice by-products such as broken rice and bran for pig feed (Bureau of Animal Nutrition Development, 2017) might lead to different results compared to studies in other regions. This study aimed to investigate the life cycle environmental impacts of slaughtered pork in Thailand through a cradle-to-slaughterhouse gate case study, considering relevant stages of pig farming and slaughtering. In addition, the effects of different pig feed formulas and allocation methods on the life cycle impacts were also compared.

2. METHODOLOGY

This study employed the Life Cycle Assessment (LCA) method following the standards outlined in ISO 14040 and 14044 by the International Organization for Standardization (ISO, 2006a; ISO, 2006b). These standards define the four main phases of an LCA, comprising goal and scope definition, life cycle inventory, life cycle impact assessment, and interpretation.

2.1 Goal and scope definitions

The objective of this study was to investigate the environmental impacts of slaughtered pork throughout its life cycle. The functional unit for the assessment was 1 kg of packaged average pork cuts obtained from a whole carcass. Inedible parts were considered bio-waste. The system boundary of this research was defined as a cradle-to-slaughterhouse gate (Figure 1). The system was divided into three main phases: pig breeding, pig farming, and slaughtering. Primary data on pig farming were derived from four pig farms in a central province of Thailand, while data on slaughtering were collected from a slaughterhouse located in an adjacent area. Secondary data on pig breeding and the background system were supplemented from existing literature as well as the LCI database, Ecoinvent 3.4, embedded in OpenLCA software. The database used was based on the allocation of the point of substitution (APOS) system model. The default allocation method in this study was based on an economic approach to avoid overestimation for lower-valued by-products (Williams and Eikenaar, 2022). The environmental impacts of the product system were assessed based on the ReCiPe 2016 midpoint (Hierarchist) method (Huijbregts et al., 2017). Four categories were selected to be highly relevant to the product system, including global warming, land use, water consumption, and freshwater eutrophication.

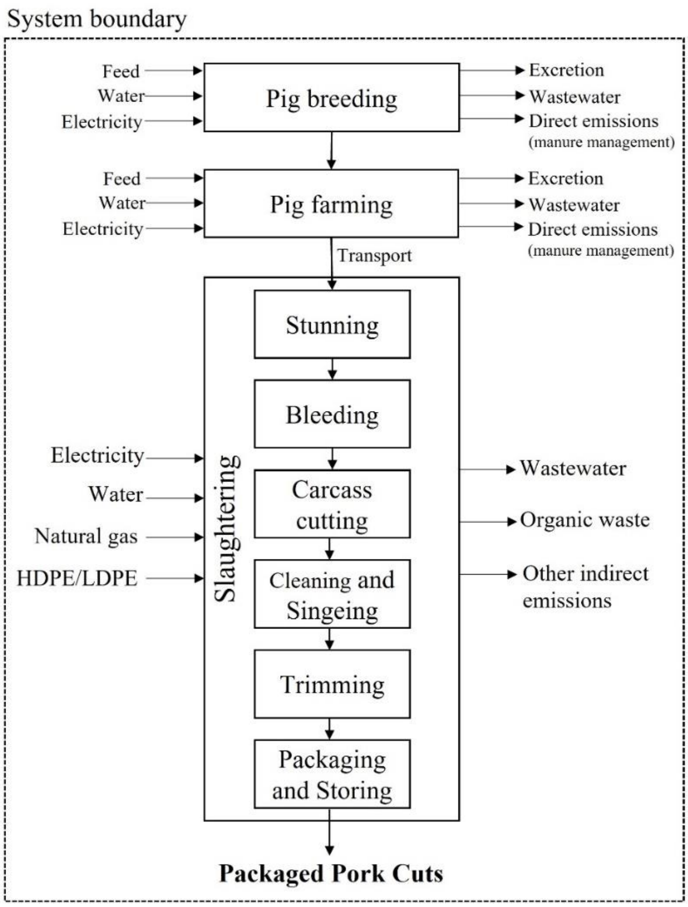

Figure 1. System boundary of slaughtered pork product system

2.2 Life cycle inventory

The product system comprised three main phases: pig breeding, pig farming, and slaughtering. Pig breeding focuses on managing boars and sows to produce healthy piglets. Pig farming is associated with the utilization of resources for raising pigs. The adult pigs are then transported to the slaughterhouse. There are six sub-processes at the slaughterhouse to produce the final product (packaged pork), including stunning, bleeding, carcass cutting, cleaning and singeing (hair removing), trimming, and packaging. The acquisition of data and assumptions used in the analysis for each life cycle stage are described as follows:

2.2.1 Pig breeding

During the breeding stage, sows are bred to produce piglets. Data on pig breeding, boar and sow handling, feed, water, and medication requirements were obtained from the Department of Livestock Development (DLD, 2005). This study assumed a sow could deliver 30 piglets annually (10 piglets/litter, 3 litters/year). Wastewater generation and direct emissions from manure, including methane (CH_4), nitrous oxide (N_2O), and ammonia (NH_3), were considered. Pig excretions were washed with water and discharged into a lagoon. The characteristics of wastewater were calculated based on data from the Pollution Control Department (2017). Direct greenhouse gas emissions from enteric fermentation and pig manure were calculated using the IPCC (2006) method, while ammonia emission was calculated based on IAEA (2008). Table 1 shows the data inventory associated with the pig breeding process to produce one weaning piglet.

2.2.2 Pig farming

Primary environmental data for pig farming were collected from four pig farms, focusing on raising weaning piglets (over 10 weeks old) with an average weight of 15 kg. The raising process primarily relied on pig feed and water. Pig feed was transported from the feed supplier to the pig farm over an average distance of 36.25 km by a 10-wheel truck. Additional inputs during this stage included disinfectants for cleaning pig houses, food supplements, and vaccines and medicines. Similar to the breeding stage, wastewater and direct air emissions were considered. A summarized inventory analysis of the farm process per pig is presented in Table 2, providing an overview of the resources and emissions associated with this stage of pig farming.

Table 1. Inventory analysis of farm production per one weaning piglet

	Quantity	Unit
Input		
Water	1.12	m^3
Transport (feed to farm)	36.25	km
Disinfectants	0.20	g
Pig feed (mixed)	36.5	kg
Output		
Piglet	15	kg
BOD (to water)	623	g
COD (to water)	1,324	g
Suspended solids (to water)	701	g
TNK (to water)	273	g
CH_4 (to air)	267	g
N_2O (to air)	11.5	g
NH_3 (to air)	98	g
Organic waste	225.34	g

Table 2. Inventory analysis of farm production per one adult pig

	Quantity	Unit
Input		
Piglet	15	kg
Electricity	17.6	kWh
Water	7.65	m^3
Transport (feed to farm)	36.25	km
Disinfectants	0.2	g
Pig feed (mixed)	375	kg
Output		
Pig (live weight)	122	kg
BOD (to water)	9.0	kg
COD (to water)	19.4	kg
Suspended solids (to water)	10.8	kg
TNK (to water)	1.3	kg
CH_4 (to air)	3.29	kg
N_2O (to air)	0.14	kg
NH_3 (to air)	1.31	kg
Organic waste	375	kg

2.2.3 Feed

To understand how variations in feed formulas can have environmental effects, this study analyzed life cycle scenarios for pork production using different feed formulations. The three main feed formulas in this study, based on Wanasitthachaiwat and Rojanasathit (1999), are summarized in Table 3. Each formula met the key requirement of pig feed recommended by DLD (2005): a crude protein content of at least 18%. The nutritional content of each feed formula, calculated based on the INRAE-CIRAD-AFZ feed tables (INRAE-CIRAD-AFZ, 2021), is specified in Table 3. Maize and rice bran are generally used as the key ingredients supplemented by sorghum and soybean meal. In scenario 1 (the baseline scenario), pig feed was produced from a mixture of maize as the main raw material, followed by soybean meal, rice bran, and other minor ingredients. In scenario 2, rice bran and maize were the main raw materials, along with a mixture of sorghum, soybean meal, and other ingredients. In scenario 3, a large proportion of rice bran was applied, followed by sorghum and soybean meal without maize.

2.2.4 Slaughtering

Adult pigs with an average live weight of 122 kg were transported to the slaughterhouse by a 10-wheel truck over an average distance of 148.61 km. There were six sub-processes in the slaughterhouse, as depicted in Figure 1. The pigs were cleaned before being passed to the stunning and bleeding units. The pig carcasses were then cut and separated into various parts. All parts were cleaned with water. Parts with skin were singed to remove hair. Finally, the pork cuts were trimmed and packed in plastic packages. After processing, the weight of the pork cuts from the whole carcass was reduced to 96.26 kg. This process generated wastewater and organic wastes (approximately 20% of live weight), including bones, bristles, and fat. A summarized inventory of the data for the slaughter process per whole carcass is presented in Table 4.

Table 3. The environmental inventory for three pig feed scenarios (per 100 kg of feed)

	Scenario 1	Scenario 2	Scenario 3
Maize (kg)	61.3	25.2	-
Rice bran and broken rice (kg)	13.3	25.2	28.8
Soybean meal (kg)	17.8	17.9	12.2
Sorghum (kg)	-	23.9	51.3
Fish meal (kg)	5.95	5.95	5.95
Dicalcium phosphate (kg)	1.30	1.30	1.30

Table 3. The environmental inventory for three pig feed scenarios (per 100 kg of feed) (cont.)

	Scenario 1	Scenario 2	Scenario 3
Sodium chloride (kg)	0.25	0.25	0.25
Multivitamin (kg)	0.18	0.18	0.18
Crude protein (%)	18.0	19.3	18.0
Crude fat (%)	4.3	5.7	5.9
Crude fiber (%)	3.2	2.8	2.6
Net energy (kcal)	229448	216216	216216

Table 4. Inventory analysis of the slaughterhouse production of pork cuts per whole carcass

	Value	Unit
Input		
Pig (live weight)	122	kg
Water	0.49	m^3
Electricity	17.1	kWh
Natural gas	0.96	kg
Transportation from farm to slaughterhouse	148.61	km
HDPE	306.0	g
LDPE	14.3	g
Output		
Pork	96.26	kg
Organic waste (bone, bristles, etc.)	25.74	kg
Wastewater	0.35	m^3
BOD	8.66	kg
COD	11.55	kg
Organic nitrogen	1.64	kg
Ammonia nitrogen	0.08	kg

3. RESULTS AND DISCUSSION

3.1 Life cycle impact assessment

Life cycle environmental impacts (LCIA) were assessed by the ReCiPe 2016 midpoint (H) approach considering four impact categories, comprising global warming (GW), freshwater eutrophication (FE), land use (LU), and water consumption (WC). The LCIA results can be described as follows:

3.1.1 Baseline scenario

The characterization results of midpoint impact categories are summarized in Table 5. Figure 2 shows the comparison of results across three scenarios displayed on a percentage share by setting the greatest result to 100%. The impact assessment results for 1 kg of packaged pork cut demonstrated the pig farming stage made the greatest contribution, exceeding 85% across all impact categories. The total carbon footprint was 5.07 $kgCO_2$-eq. The key contributor to this footprint arose from the production of maize used in pig feed, as well as direct emissions (CH_4 and N_2O) from pig slurry. Considering activities and inputs specifically in the pig farming process (Figure 3), maize was the main raw material in pig feed. The cultivation of maize also significantly impacted FE, LU, and WC.

Maize cultivation, especially with fertilizer use, contributes to eutrophication by causing an imbalance in soil and water nutrient levels (N and P) (Powers, 2005). In terms of the impact on LU, maize and soybean meal contributed equally. Large-scale maize farming often involves monoculture practices, dedicating extensive areas solely to maize. This practice reduces biodiversity and disrupts natural ecosystems (Fuchs et al., 2021). In addition, soybean feed production has been linked to land use change and deforestation, especially in South America (Rajão et al., 2020). While the amount of rice bran in the pig feed was relatively low, its impact was almost as significant as maize. The results suggested that rice cultivation requires significantly more water than maize. Studies revealed that rice cultivation in tropical regions may necessitate nearly double the water usage compared to maize (2,497 L/kg versus 1,222 L/kg) (Rahaman and Shehab, 2018).

Table 5. Comparison of impacts in different feed scenarios (per functional unit)

		GW ($kgCO_2$-eq)	FE (kgP-eq)	LU (m^2a-eq)	WC (m^3)
Scenario 1	Breeding	3.96E-01	8.88E-05	4.16E-01	4.02E-01
	Farming	4.50E+00	9.92E-04	4.28E+00	4.35E+00
	Slaughtering	1.77E-01	8.22E-05	2.66E-03	2.10E-01
	Total	5.07E+00	1.16E-03	4.69E+00	4.97E+00
Scenario 2	Breeding	3.73E-01	6.67E-05	2.83E-01	4.06E-01
	Farming	4.27E+00	7.65E-04	2.92E+00	4.40E+00
	Slaughtering	1.77E-01	8.22E-05	2.66E-03	2.10E-01
	Total	4.82E+00	9.14E-04	3.20E+00	5.02E+00
Scenario 3	Breeding	3.24E-01	4.35E-05	1.31E-01	3.60E-01
	Farming	3.77E+00	5.26E-04	1.35E+00	3.93E+00
	Slaughtering	1.77E-01	8.22E-05	2.66E-03	2.10E-01
	Total	4.27E+00	6.52E-04	1.49E+00	4.50E+00

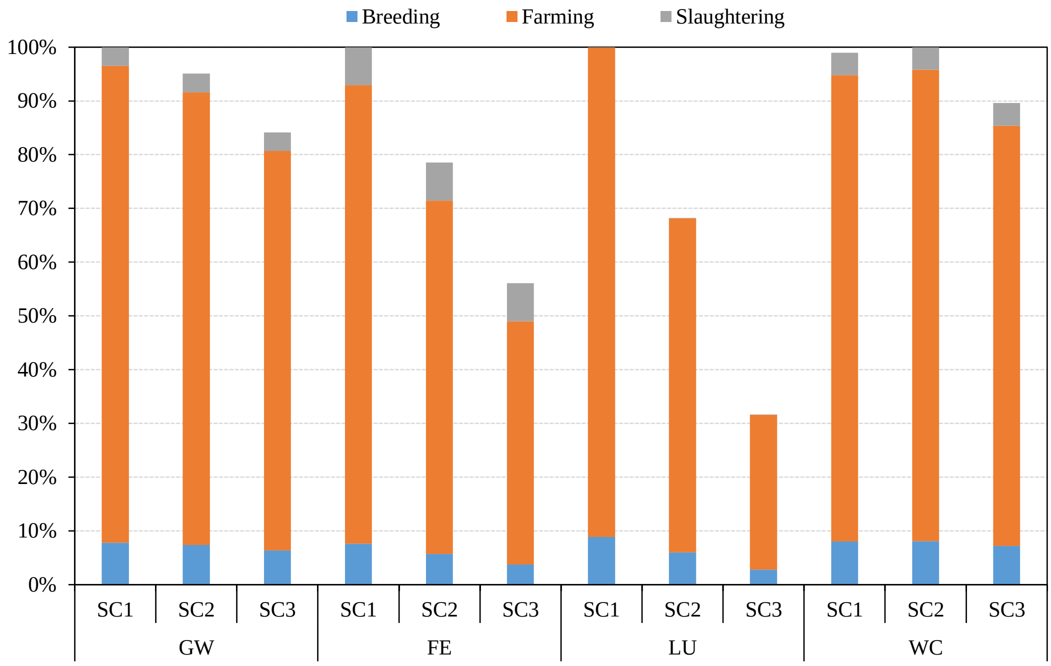

Figure 2. Impact assessment results of different feed scenarios

3.1.2 Alternative feed scenarios

In comparing the feed scenarios (Figures 2 and 3), the baseline scenario emerged as the one with the most significant impact on GW, FE, and LU, primarily due to its heavy reliance on maize, as discussed earlier. Scenario 3, on the other hand, had the lowest environmental impact across all categories. Scenarios 2 and 3 aimed to reduce the environmental impact of maize production on GW, FE, and WC by substituting raw materials. However, this substitution resulted in a proportional increase in the impact of rice. Since rice is a water-intensive crop, the higher proportion of rice bran for pig feed in Scenario 2 led to a greater impact on WC compared to the baseline scenario. Similar to the baseline scenario, maize and soybean remained the primary contributors to LU in Scenarios 2 and 3. Substituting maize with sorghum, particularly in Scenario 3, significantly reduced the impacts on FE and LU. Sorghum's high nitrogen usage efficiency and lower water requirement (one-third less than maize) make it a low-impact crop (Duff et al., 2019).

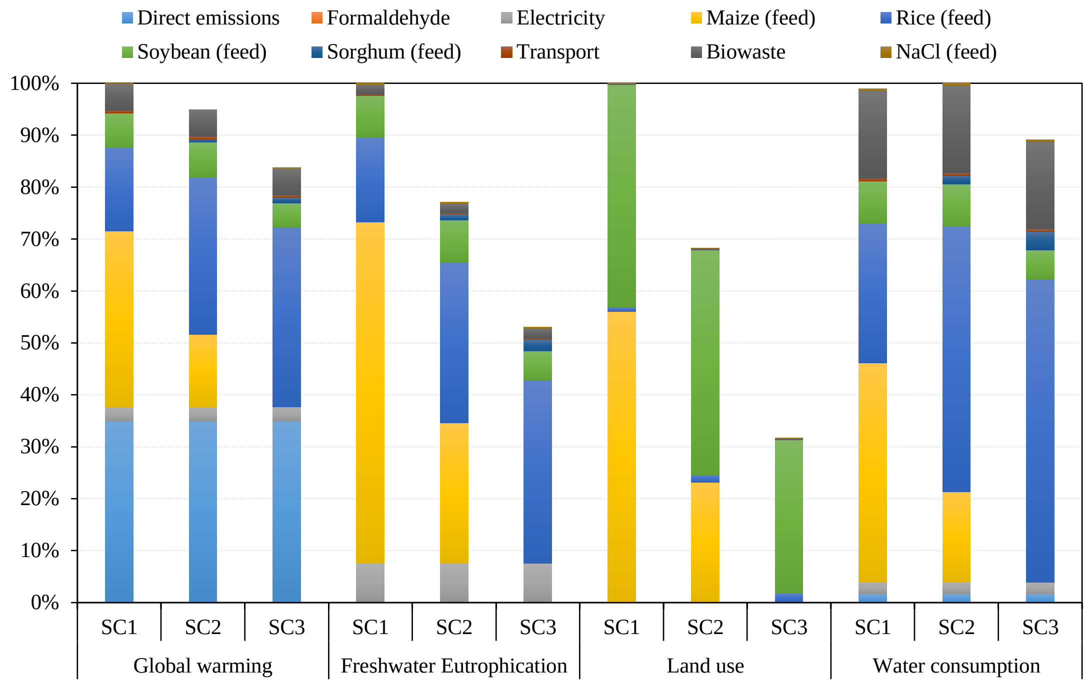

Figure 3. Comparison of impact contribution from pig farming in different scenarios

3.2 Sensitivity analysis

3.2.1 Variability of parameters

This study analyzed the impact of uncertain data in pork production through sensitivity analysis to identify the parameters that significantly influence the final results. This information can then be used to improve the reliability of the LCA and identify areas where further data collection is needed. Parameters with a percentage coefficient of variation (%CV) of at least 10% were selected and varied by ±10%. The impact on the product life cycle assessment (LCA) results was then assessed to identify the level of influence.

Six parameters were identified as having significant variability, including transport feed, HDPE, LDPE, water, organic waste, and slaughterhouse wastewater. Table 6 shows the changes in the three impacts resulting from the variation of these parameters. However, these changes had a minimal effect on the results of the overall sensitivity analysis (less than 1% impact). This suggested that, while some individual parameters might influence specific impact categories, the overall data used in the test was relatively robust to these variations.

3.2.2 Allocation method

The default allocation method in this study was based on economic value because the mass-based approach can lead to overestimation for lower-valued by-products (i.e., rice bran and broken rice) (Williams and Eikenaar, 2022). The average selling prices for rice (THB 20.40 per kg of rice) and its by-product (THB 11.47 per kg of rice bran) in 2023 (Ministry of Commerce, 2024) were used to calculate the default allocation factor. In this section, physical allocation was performed to investigate the effect of the allocation method on the LCA result. For every 1 kg of paddy rice processed in a mill, 0.1 kg of rice bran and broken rice are generated. Therefore, approximately 10% of the environmental burden from rice production was assigned to by-products.

Table 6. Sensitivity of impact results responding to parameter variations (±10%)

Parameter	%CV	%Sensitivity			
		GW	FE	LU	WC
Transport (feed to farm)	13.95	0.047	0.016	0.002	0.041
Organic waste (slaughterhouse)	23.83	0.032	0.012	0.002	0.103
HDPE (slaughterhouse)	29.43	0.004	0.012	0.000	0.011
LDPE (slaughterhouse)	29.43	0.001	0.000	0.000	0.000
Water (slaughterhouse)	17.05	0.000	0.000	0.000	0.010
Wastewater (slaughterhouse)	23.59	0.003	0.033	0.000	0.032

Table 7. Comparison of LCA results using physical and economic allocation methods

	Allocation method	GW ($kgCO_2$-eq)	FE (kgP-eq)	LU (m^2a-eq)	WC (m^3)
Scenario 1	Economic	5.07E+00	1.16E-03	4.69E+00	4.97E+00
	Physical	5.63E+00	1.29E-03	4.72E+00	5.88E+00
	%change	10.92%	10.70%	0.57%	18.36%
Scenario 2	Economic	4.82E+00	9.14E-04	3.20E+00	5.02E+00
	Physical	5.87E+00	1.15E-03	3.25E+00	6.75E+00
	%change	21.79%	25.83%	1.58%	34.47%
Scenario 3	Economic	4.27E+00	6.52E-04	1.49E+00	4.50E+00
	Physical	5.47E+00	9.22E-04	1.54E+00	6.47E+00
	%change	28.13%	41.37%	3.88%	43.97%

Utilizing the physical allocation method (as shown in Table 7) significantly increased the overall environmental impact compared to the economic allocation method, particularly in Scenario 3 with its heavy reliance on rice bran and broken rice in the feed formulation. This effect was most noticeable in FE and WC, where rice production is the key contributor. These results highlight the significant impact that the method selected for allocating environmental burdens from agricultural by-products in pig feed can have on the overall LCA findings.

3.3 Discussion

This study reaffirmed that an environmental hotspot of pork production was pig feed, consistent with previous studies (e.g., Pazmiño and Ramirez, 2021; Liu et al., 2021; Zira et al., 2021). The main ingredients of pig feed, particularly maize and rice by-products, played an important role in contributing to environmental impacts. Although the results of LCA are unable to be compared directly due to variations in methodology and system boundaries, a comparison of global warming or carbon footprint results, a key environmental concern, was conducted. As shown in Table 8, the life cycle GWP of pork can vary significantly, ranging from 2.46 to 9.04 $kgCO_{2\text{-eq}}$ per kg of pork at the slaughterhouse gate. Such variations likely stem from different data limitations, production practices, feed composition, and waste management scenarios. In the present study, Scenarios 1-3 yielded GW values of 5.07, 4.82, and 4.27 $kgCO_2$-eq/kg of pork cut, respectively, which fall within the range identified in the literature review with an average value of 4.63 $kgCO_2$-eq.

Table 8. Comparison of global warming potential impact results with other studies

Reference	Scenario/Country	GWP ($kgCO_2$-eq/FU[1])
Ndue and Pál (2022)	Conventional, EU	2.46
	Organic, EU	4.27
Pazmiño and Ramirez (2021)	Economic allocation, Ecuador	4.57
Liu et al. (2021)	Small-scale production, China	5.96
Reckmann et al. (2016)	Standard diets, Germany	3.01
Winkler et al. (2016)	Australia	4.75
Djekic et al. (2015)	Serbia	9.04
Nguyen et al. (2011)	Denmark	2.95

[1]Functional Unit: 1 kg of pig carcass or pork at the slaughterhouse gate

Pig feed composition significantly influences the life cycle impacts of pork products. In Europe, wheat, barley, and maize are commonly used feed ingredients supplemented with soybean meal (Djekic et al., 2015; Reckmann et al., 2016). However, this reliance on soybean meal creates an environmental concern, as it is often imported from South American countries where deforestation for soy cultivation is a significant issue (Rajão et al., 2020). Conversely, Asian pig feed relies primarily on maize and soybean meal (Liu et al., 2021; Ogino et al., 2013). Burning agricultural residues, such as maize stalks and rice straw, is currently a major environmental concern in Asia. This practice discharges large quantities of fine particulate matter (PM2.5) directly into the atmosphere and leads to serious health problems in Southeast Asia (Oanh et al., 2018).

The scenario analysis in this study, investigating different feed options in Thailand, indicated that combining rice by-products (rice bran and broken rice) with sorghum had the potential to mitigate environmental impacts. However, rice use necessitates optimization as its cultivation requires a significant quantity of water. Although Thailand is located in a tropical, humid area, the country faces various challenges related to water availability, quality, and management. The increase in water demand due to population growth, the rapid growth of spatial development and economy, etc. causes water shortages (Wijitkosum and Sriburi, 2008). In addition to water consumption, rice cultivation requires fertilizers and contributes directly to greenhouse gas emissions. Apart from rice by-products, sorghum boasts a lower environmental footprint compared to maize and rice (Duff et al., 2019). Nonetheless, domestic production in Thailand is currently low, necessitating heavy reliance on imports (DOAE, 2019).

Several management strategies have been recommended to improve the environmental performance of pig feed. The substitution of crude protein content from soybean meal with, for example, synthetic amino acids can potentially reduce the overall environmental impact of pig feed and consequently lower N and CH_4 excretion of pigs (Ogino et al., 2013; Reckmann et al., 2016). The utilization of precision feeding techniques, which involves providing the right amount of feed with the perfect mix of nutrients at the right time, can reduce production costs and greenhouse gas emissions (6% lower) (Pomar and Remus, 2019). Dry legume seeds, particularly when combined from different species, offer the most accessible protein alternative to soybean; they can be effectively incorporated into pig diets without compromising meat quality (Parrini et al., 2023). Some countries incorporate recycled food waste into pig feed, which can be a sustainable practice if managed hygienically. Heller et al. (2018) highlighted feeding pigs with recycled food waste as a management strategy that can mitigate the associated greenhouse gas emissions by 24%. However, controversy about animal welfare and environmental sustainability emerges (Ndue and Pál, 2022).

Apart from feed management to improve the system, adequate management of farm waste is still required, even though manure and wastewater from pig production have a relatively low environmental impact. These residues can be utilized for generating biogas, fertilizers, and compost that can be used in feed production practices, subsequently reducing the life cycle impact of pork production. During the slaughtering process, all by-products should be prioritized for use as food or animal feed. For any inedible by-products, rendering or converting them into usable products should be strongly encouraged. This approach reduces reliance on virgin resources and promotes a more sustainable life cycle for pork production. Future research should prioritize the environmental impact of feed production, as it appears to have been the most significant contributor in this study. Due to data limitations, only three feed formulas were analyzed. However, investigating alternative feed ingredients, specifically from local crops or agricultural by-products, is crucial. Furthermore, the impact of these alternative feed nutrients on pig growth and biomass production should be explored.

4. CONCLUSION

A life cycle assessment was conducted to evaluate the environmental effects of 1 kg of average packaged pork cut from a whole carcass. This study identified the environmental impact of each stage of the pork life cycle and pinpointed hotspots for improvement. Three scenarios for feed composition were also assessed. The baseline scenario results showed that maize production in pig feed was the key contributor to all three key environmental damage categories, followed closely by rice production. The substitution of rice by-products and sorghum in Scenarios 2 and 3 tended to reduce the magnitude of any impact. On the other hand, rice cultivation requires a significant amount of water as well as fertilizers and is directly related to greenhouse gas emissions. Moreover, the method chosen for allocating environmental impacts from agricultural by-products in pig feed can significantly affect the overall results. The reason is that the mass of the by-products is typically much greater than their economic value compared to the main product. Significant opportunities exist to improve the environmental impact of pork production, with a focus on feed production strategies. This can be achieved by substituting ingredients with high environmental footprints for more sustainable alternatives. Additionally, utilizing the waste from pig farming and slaughtering can further reduce the environmental impact. This information can be used by pig farmers, slaughterhouse owners, suppliers, and other stakeholders to enhance their environmental performance.

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