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JOINT BENCHMARKING AND ECO-EFFICIENCY FOR THE SUSTAINABLE PERFORMANCE OF SWINE PRODUCTION IN THAILAND

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ABSTRACT: This research aimed to develop the sustainable performance of swine production through joint benchmarking and eco-efficiency. The economic and environmental performance of 15 swine farms in Thailand between 2011 and 2013 were evaluated by Gate to Gate sector boundary. The results showed that the highest and lowest values of eco-efficiency in the swine farming sector were feed and water consumption, respectively. Benchmarking of eco-efficiencies in all indicators demonstrated that best practice for swine farms was obtained with average feed consumption of 1 kg-head-day, average water consumption of 1.17 L/head-day, use of renewable energy from biogas of 0.014 kWh/head-day, use of swine fever vaccination and anthelmintics, greenhouse gas emissions of 0.00875 ton CO_2-eq/head-day and total amount of waste produced of 6.25 kg/head-day. Lastly, the sustainable development of a recommended approach for swine production in Thailand, which includes breeding selection, husbandry management, farm management and attendance, and the environmental management of farms was developed using material flow analysis concepts, in-depth interview and brainstorming with best practice swine farmers.

Keywords: Benchmarking; Eco-Efficiency; Sustainable Performance; Swine Production; Thailand.

1. INTRODUCTION

The concept of environmental sustainability applies to operations management within food and agricultural systems [1]. In Southeast Asia, Thailand is the largest producer of swine with 13.07 million pigs in 2013 [2]. Nuengjamnong and Rachdawong [3] investigated environmental impact issues within the industry, noting that the size of swine farms has shifted from small to large-scale operations. Additionally, consumers in developed countries demand safe food of high quality produced with minimal adverse environmental impact [4]–[7].

A feasible and increasingly adopted approach to measure sustainability at an individual level is represented by eco-efficiency, which appeared in the 1990s as a practical tool to measure sustainability. The World Business Council for Sustainable Development [8] introduced the term “eco-efficiency” as identifying a management philosophy aimed at encouraging businesses to search for environmental improvements that yield parallel economic benefits. Eco-efficiency studies were used to assess performance and identify opportunities for improvement [9]. This concept, together with integrative design, offers an opportunity to substantially improve eco-efficiency. A number of previous studies [10]–[11] have investigated effective methods of linking benchmarking and eco-efficiency to improve agricultural operations. This study uses benchmarking and the concept of eco-efficiency with the objective of performing an eco-efficiency assessment of swine farms in Thailand. In addition, a joint study was conducted to identify the best performing farms for use in public policy to improve the eco-efficiency of swine farm production.

2. METHODS

2.1 The swine farm production process

According to a previous study [3], verified in a swine farm in the southern part of Thailand, the first step in swine farm production is swine breeding. Pregnant swine are given water and feed for four months. Then, vaccines, energy, water, and feed are needed to care for the piglet for one month, or until they have reached 16 kg in body weight. Piglets are separated into two groups: those sold directly and swine grown for a further forty days. In addition, this step in swine production produces significant waste from swine feces and wastewater from the floor and corral cleansing, which can be directed to a biogas system or preliminary treatment before environmental discharge (Fig. 1).

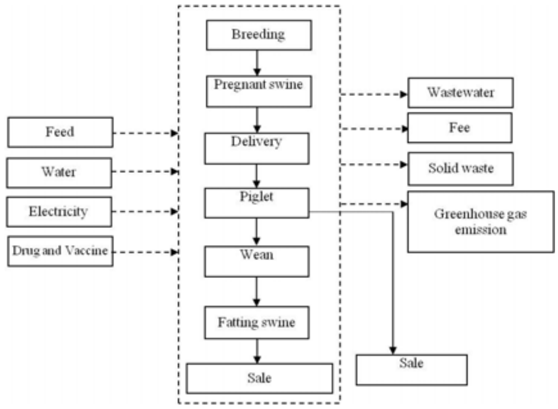

Fig. 1 The swine farm production process

2.2 Eco-efficiency indicators and data collection procedure

The eco-efficiency assessment of swine farm production requires an extensive review of the literature and farm surveys, including inputs, outputs, and by-products. Eco-efficiency indicators consist of economic and environmental indicators (Table 1). A questionnaire was developed to collect data on the selected indicators, based on a questionnaire developed by the National Round Table on the Environment and the Economy [12]. This questionnaire was approved by the Social Ethical Committee of Mahidol University.

The environmental and economic performances of 15 swine farms in the southern and central parts of Thailand between 2011 and 2013 were collected based on farm size recommendations of the Pollution Control Department, Thailand, including small (50–500 pigs), medium (500–5,000 pigs), and large (more than 5,000 pigs) farms.

Table 1 Eco-efficiency indicators of swine production in Thailand

Indicators	Unit
Economic indicator	
Net sale	Baht/year
Environmental indicator	
Feed consumption	Ton/year
Drug and vaccine consumption	mL/year
Electricity consumption	kWh/year
Water consumption	m^3/year
Waste production	Ton/year
Greenhouse gas emission	Ton CO_2-eq/year

2.3 Eco-efficiency assessment

The eco-efficiency assessment of swine farm production was modified from key concepts of the World Business Council for Sustainable Development [8] and a previous study [13], measured using the ratio between swine production value and total environmental impact from the production process. The eco-efficiency calculation is shown in equation (1).

$$E = EV/\ \Sigma En \qquad (1)$$

Where: E is the eco-efficiency value; EV is the economic value of swine production; ΣEn is the total environmental impact from the material and resource use of swine production.

2.4 The recommended approach of swine production toward sustainable development by joint benchmarking and eco-efficiency concept

The eco-efficiency values of swine farm production were used to identify best practice by benchmarking the value of each indicator. Firstly, indicator units were normalized before benchmarking, then the eco-efficiency value of each indicator was benchmarked to identify best practice performance. The concept of material flow analysis [13] was used to confirm the process of best practice farm in each indicator. Finally, in-depth interviewing and brainstorming with farm owners were included for approach verification and then the recommended approach of swine production for sustainable management in Thailand was developed.

3. RESULTS AND DISCUSSION

3.1 Eco-efficiency value of swine farm production

The resulting eco-efficiency values of swine farm production are shown in Table 2. The eco-efficiency values of small farms are highest and lowest for electricity consumption and greenhouse gas emissions, respectively. Additionally, the trend for eco-efficiency values increased annually for small farms. However, the net sale of swine production was slightly increased due to the increased cost of feed. The main advantage of small size farms was identified as labor cost savings because they are family-run.

The highest and lowest eco-efficiency values for medium farms were electricity and water consumption, respectively (Table 2). These findings show that the swine production process, including heating, ventilation and water pumping, requires a significant electricity supply. Additionally, the water consumption trend increased annually due to swine drinking-water and corral cleaning twice daily.

The highest and lowest eco-efficiency values for large farms were water and electricity consumption, respectively (Table 2). This finding is consistent with the medium farms in the issue of water consumption. Vu *et al.* [14] found that the volume of water consumption was 40 L/swine for corral and floor cleaning, which was similar to the results of this study. However, the inlet water system and the reuse of treated wastewater were applied in this farm size for reducing water consumption. Additionally, biogas production systems can be used to reduce electricity consumption in large farms with the lowest eco-efficiency value in this study.

3.2 Benchmarking value of eco-efficiency for swine production

The results of the eco-efficiency assessment of 15 swine farms were used to identify best practice performance by benchmarking. This data is shown in Table 3. Regarding feed consumption, the best practice swine production with eco-efficiency values of 58,159.70 baht/ton was Swine farm K, as the tablet type of feed and feed limitation and control at 0.12 ton/head-year with twice daily feeding was used. Regarding water consumption, farm C had the best practice with eco-efficiency values of 14,679.94 baht/$m^3$and 1.17 L/head-day of water consumption, since well water was pumped to a large storage tank for supplying swine drinking water needs and daily cleaning. Farm O had the best practice regarding electricity consumption, with eco-efficiency values of 5,642.25 baht/kWh and 1.72 kWh/head-year. A biogas system using farm wastewater provided all energy needed at a cost of 394 baht/month. In the case of drug and vaccine consumption, farm A had the best practice with eco-efficiency values of 2,208.77 baht/mL and 8.38 mL/head-year. Concerning waste production, an average eco-efficiency of 12,998.90 baht/ton and 6.25 ton/head-year were found in farm O, as biogas production supported by the government was used to treat both wastewater and solid waste to cover the energy consumption costs of this farm. Finally, farm O also presented the best practice in greenhouse gas emissions, with eco-efficiency values of 9,260.22 baht/ton CO_2-eq and 0.00875 ton CO_2-eq/head-year.

3.3 The recommended approach of swine production toward sustainable development

Using the results of swine production eco-efficiency benchmarking to identify best practices, the master approach of swine production toward sustainable management was developed using material flow analysis, in-depth interviews and brainstorming with the best practice farms within each indicator. The recommended approach consisted of two paradigms including a technical approach to process improvement and a management approach with farm improvement. The details of the master approach of swine production toward sustainable development are shown in Fig. 3 and consist of four components. Firstly, breeding selection should be based on rapidly growing, disease-resistant animals. Secondly, the master approach of husbandry management consists of animal health, and feed and water consumption management. For animal health management, swine farmers should provide drug and vaccine doses based on government regulations. Additionally, pathogen contamination prevention techniques should be implemented as standard. Feed and water consumption management should provide for the demands of swine based on the growing stage. Swine feed can be prepared by farmers, reducing cost. Moreover, feed storage buildings should be separate, protecting from human, insect and pathogen contamination. To provide clean water for drinking, water storage tanks and pipes with nozzles are recommended to reduce water consumption. Thirdly, farm management and attendance, including corrals, staff, and document management, are proposed as part of the master approach to swine production. The master approach to corral management should be to provide clean, dry, orderly housing, and should be cleaned and sterilized twice daily. Regarding staff management, a suitable ratio of personnel/swine is one person per 200 swine, together with one veterinary specialist. The documentation management of farms, including administration, productivity management, and product and by-product volumes should be developed for data backup and use. Lastly, sound environmental management of farms should be included in the master plan of swine management. All wastewater and feces produced should be collected and treated before environmental discharge. Biogas production systems are recommended as part of the waste management of swine farms, as they produce environmentally friendly energy from waste by-products. The reuse of solid waste in swine farms should be implemented.

4. CONCLUSION

The research objective was to examine the sustainable performance of swine farm production in Thailand using a joint eco-efficiency and benchmarking technique. A suitable measure of

Table 2. Eco-efficiency value of swine production

Indicators	Unit	Eco-efficiency value								
		Large farms			Medium farms			Small farms		
		2011	2012	2013	2011	2012	2013	2011	2012	2013
Feed consumption	Ton/year	26,148.99	22,270.51	23564.67	12,868.14	14,060.16	16,802.43	7,269.69	8,716.32	11,759.55
Drug and vaccine consumption	mL/year	992.49	824.06	1008.67	999.33	1,098.99	1,322.49	460.15	558.26	773.48
Electricity consumption	kWh/year	3,243.52	2,724.78	3,289.61	333.81	367.55	441.91	196.54	238.96	333.70
Water consumption	m^3/year	327.12	272.64	332.15	1,046.05	1,150.09	1,379.83	2,468.17	2,985.72	4,103.77
Waste production	Ton/year	11,390.58	9,559.36	11,594.21	5,522.60	6,045.79	7,224.13	2,559.34	3,105.30	4,242.03
Greenhouse gas emission	Ton CO_2-eq/year	5,323.36	4,471.99	5,399.00	547.85	603.23	725.27	322.57	329.19	547.61

Table 3. Benchmarking of eco-efficiency for swine production

Indicators	Swine farms														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Feed consumption (Baht/ton)	31,147.90	2,529.94	17,973.95	2,630.20	12,011.69	3,320.59	4,038.11	3,415.81	11,262.90	19,595.18	58,159.70	12,254.52	22,495.51	38,930.39	9,846.50
Drug and vaccine consumption (Baht/mL)	2,208.77	233.67	1095.81	182.83	332.71	713.06	700.29	888.17	1,396.84	727.58	1,960.98	1,071.90	368.44	1,499.96	2,208.77
Electricity consumption (Baht/kWh)	1,208.78	84.11	487.30	87.77	337.48	29.24	147.72	135.75	582.84	242.39	526.53	388.13	1,781.87	1,285.11	5,642.25
Water consumption (Baht/m^3)	5,594.65	729.10	14,679.94	605.94	7,649.04	5,419.89	1,511.32	1,004.24	3,513.56	5,160.11	3,851.03	791.61	7,495.14	164.18	232.05
Waste production (Baht/ton)	11,326.88	1,090.28	6136.69	907.34	2,300.12	2,255.68	3,783.69	1,172.60	5,433.88	6,359.17	7,429.58	6,964.70	8,340.94	7,342.65	12,998.90
Greenhouse gas emission Baht/ton CO_2-eq)	1,983.88	138.05	799.77	144.04	553.89	3,675.28	2,680.97	220.80	956.57	397.82	864.15	637.00	2,888.38	2,109.16	9,260.22

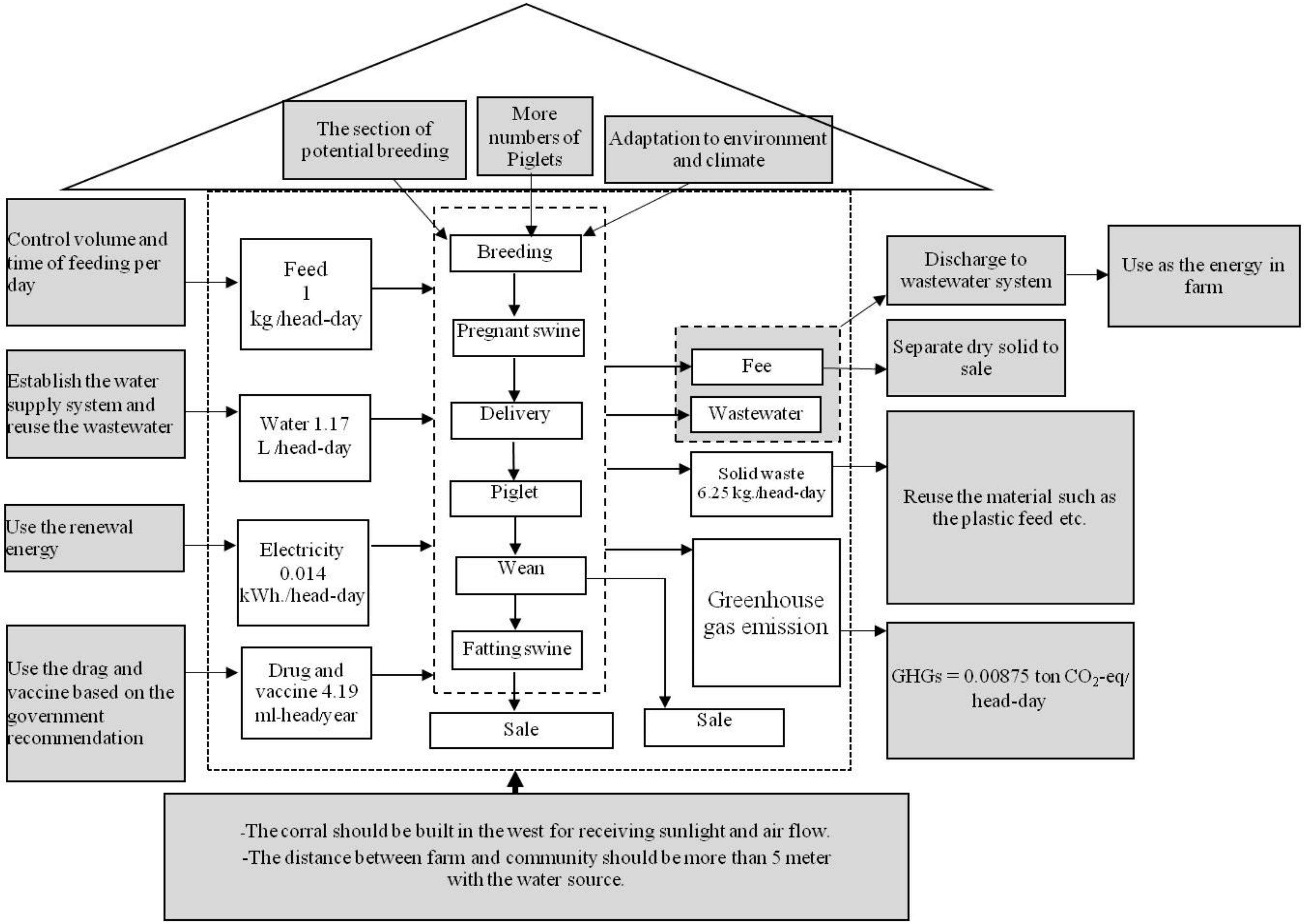

Fig. 2 Master approach of swine production toward sustainable development

eco-efficiency values of swine production were developed and used to generate a questionnaire for collecting data on the economic and environmental performance of 15 swine farms in Thailand. Consequently, eco-efficiency values and benchmarking were combined to identify best practices for a proposed master approach of sustainable swine production. The results showed an evident difference, as small- and medium-sized farms were concerned with water consumption, and large farms were most concerned with heating and cleaning issues. Then, joint benchmarking and eco-efficiency values were used to ascertain the best practices in swine production. These results identified that best practice attained 1.17 L/head-day water consumption, 0.014 kWh/head-day electricity consumption, 0.00875 ton CO_2-eq/head-year greenhouse gas emission, and 6.25 ton/head-year waste production. Finally, best practice in breeding selection, husbandry management, farm management and attendance and the environmental management of farms were identified by material flow analysis, in-depth interviews and brainstorming then included as part of the master approach to sustainable swine farm production.

5. ACKNOWLEDGEMENTS

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