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Greenhouse Gas Emissions from Deboned Milkfish Production in Thailand

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***Abstract*—Milkfish (*Chanos chanos*) is one of the fisheries products that are cultured among countries in Southeast Asia. Milkfish processing, particularly deboned milkfish, is available in the market and the demand of this product is increasing as a protein source. The increase of deboned milkfish demand in Thailand stimulates production units to expand their production line. However, the official information about the greenhouse gases (GHGs) emissions of milkfish rearing and deboned process is still unknown. The purposes of this study were to evaluate the GHG emissions from the production of deboned milkfish. The result revealed that CO_2 emission was the major GHG of the deboned milkfish production. The CO_2 emission from all units was 16.47 kg and the main source of emission was the use of electricity. The N_2O emission of all units was 4.99 kg and the major source of emission was the ebullition from milkfish ponds. Emission of CH_4 of all units was 0.06 kg and the main source of emission was the ebullition from milkfish ponds. The emissions of N_2O or NO_X exhibited the highest global warming potential in terms of $kgCO_2$ eq. This finding suggests that improvement of fish ponds environment particularly the microbial activities in the bottom of the ponds should be considered. Good practice of feeding process, water quality control and maintaining the water depth in the pond can help to reduce the GHG emission. Application of alternative energy such as wind and solar energy can help to reduce the use of electricity and the reduction of CO_2 emissions.**

***Index Terms*—Greenhouse gases, deboned milkfish, Thailand**

I. INTRODUCTION

Sustainable aquaculture is one of the interesting issues due to the crucial role of aquaculture in food and employment service [1]. Half of fisheries productions was produced to be the food for human consumption which can relieve the hunger and supplement the nutrition for people over the world. Milkfish (*Chanos chanos*) is one of the fisheries products that is cultured among countries in East Asia and Southeast Asia such as Indonesia, Philippines and the Republic of China [2]. Milkfish is a euryhaline fish that can be cultured in marine, estuarine, or fresh water aquatic systems [2]. Most of the milkfish production are derived from aquaculture. The Food and Agriculture Organization (FAO) of the United Nations reported that global production of milkfish had increased consistently. The production of milkfish in 2012 was 943.3 metric tons (MT) and increased to 1,327 MT in 2018 [3]. Milkfish aquaculture consistently evolves from traditional to semi-intensive and intensive culture. The transformation of culturing method from traditional to intensive method stimulates the need of high resources supply for the production [4]. However, milkfish is a unique fish that needs to be processed before consumption because milkfish possesses numerous bones which are not easy to remove and thus can be the obstructive reason for people to consume it. Milkfish has large spine, numerous intramuscular bones and small bones in a “Y” shape penetrating into fish muscle. These features require special methods to remove all milkfish bones in order to make the milkfish fillet available for food preparation [2]. The Philippines is the leading country that exports deboned milkfish fillet. The deboned milkfish product from the Philippines has been sent to several countries/territories—such as the United States of America, China and Republic of China [2]. In Thailand, culturing of milkfish has started since 2002 resulting from the success of breeding milkfish by the Prachuap Khiri Khan Coastal Fisheries Research and Development Centre which is the government agency of Thai Department of Fisheries [5]. Since then, people in Prachuap Khiri Khan Province were trained to remove the bone from milkfish and they can produce the commercial deboned milkfish for the market [5]. However, there is no official data of milkfish production and the amount of deboned milkfish in Thailand. The data from the report of [6] showed that the demand of deboned milkfish has increased and the supply from deboning units at Prachuap Khiri Khan Province is not enough to satisfy market demand. The increase in demand of milkfish innovates the milkfish farming and processing units to expand the production line. However, Thailand still needs more data about production of milkfish in combination with a sustainable production, particularly the production that releases low greenhouse gases (GHG). In order to initiate the new data base of GHG emissions from the milkfish production and the deboned milkfish production in Thailand, this study aims to evaluate the GHG emissions from the production of deboned milkfish. The obtained results in this study are expected to provide information for the improvement of deboned milkfish product for the sustainable fisheries production.

II. METHODOLOGY

A. Study Area

All of studied units in this study are located in Prachuap Khiri Khan Province which is in the Southern part of Central Thailand as shown in Fig. 1. The milkfish fingerlings production unit is under a Thai government work agency Prachuap Khiri Khan Coastal Fisheries Research and Development Centre. The milkfish culture unit is located in Kui Buri District of Prachuap Khiri Khan Province and the deboned milkfish unit is located in Khlong Wan Sub-district

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that is close to the fingerlings production unit.

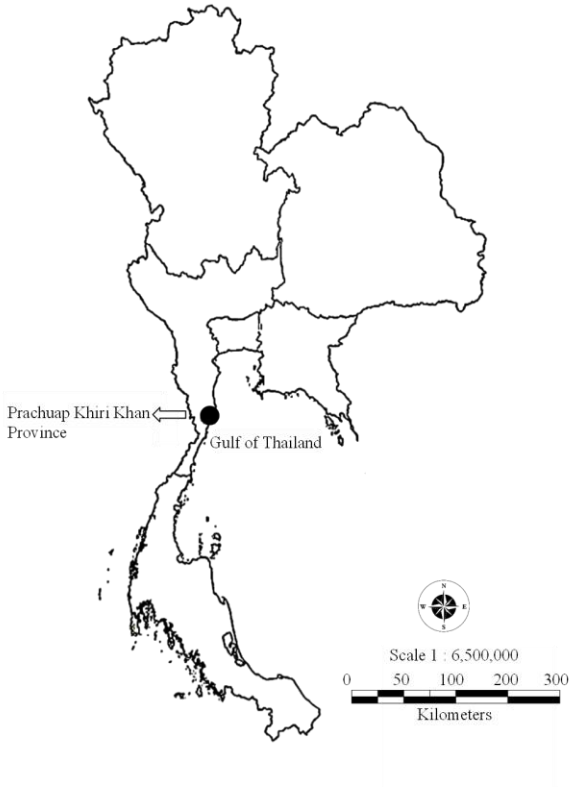

Fig. 1. Study area located in Prachaup Khiri Khan Province, Thailand.

B. Scope and System Boundary

The aim of this study focuses on quantifying the emissions of greenhouse gases from cradle to business which comprised the production chain of deboned milkfish and identifies the hot spot units that need to improve the GHG emissions. The system boundary of this study, shown in Fig. 2, was considered based on several reviewed data. The production processes of deboned milkfish comprise three units including the hatchery unit, the milkfish farming unit, and the deboning milkfish unit.

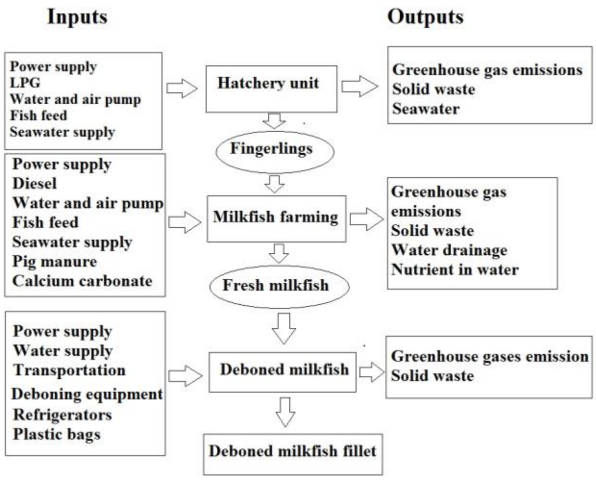

Fig. 2. System boundary of deboned milkfish fillet.

C. Functional Unit

The functional unit (FU) was considered as 0.5 kg of deboned milkfish fillet which was packed in a low-density polyethylene (LDPE) plastic bag.

D. Data Inventories

The data inventories were committed based on life cycle analysis (LCA) method [7, 8]. The inventories data focused on the inputs of material including fish feed, fuel, chemicals, manure, power supply as well as all outputs, e.g., product, solid waste and gas emissions. Data on inputs and outputs were collected by surveying and interviewing officers, farmers and workers in each unit. The data collection lasted from December 2018 to October 2019. However, the GHG emissions and all activities from the hatchery unit were determined based on a study of Pianjing and Wites [6].

E. Methodology for Quantifying GHG

The GHG emissions determination was obtained by using the calculation method based on Intergovernmental Panel on Climate Change (IPCC) [9, 10]. The emission intensity (EI) was calculated in terms of kg CO_2, kg NOx and N_2O and kg CH_4. The greenhouse gases were determined by using emission factors that has been proposed by several studies. The emission intensities were calculated regarding to the activities in each unit.

There is no specific fish feed for milkfish, therefore, the farmers use cat fish feed and shrimp feed due to the fact that these feeds comprise high protein (35%). However, there is no the data of GHG emission from cat fish feed in Thailand. Therefore, GHG emissions from fish feed used in all unit in this study were calculated based on a study of Suksathit [11]. Suksathit [11] proposed that 1 kg of shrimp feed that was used in Thailand contained protein for 35%**,** lipid for 6%, fiber for 2.5%, emitted CO_2 and CH_4 for 1.29 kg and 0.0015 kg respectively.

The emission factors (EF) of GHG including CO_2 and NOx from power supply were 589.25 g/kWh, and 1.28 g/kWh respectively. This EF were proposed by Intergovernmental Panel on Climate Change (IPCC) [12].

The amount of CO_2, N_2O, and CH_4 emissions from liquefied petroleum gas (LPG) combustion and gasoline (diesel oil for pickup truck) were calculated following the IPCC 2006 guideline [9, 10]. The emission factors of CO_2, N_2O, and CH_4 of LPG were 56100 kg of CO_2/TJ fuel, 0.1 kg of N_2O/TJ fuel, and 1 kg of CH_4/TJ fuel respectively; and the emission factors of CO_2, N_2O, and CH_4 of diesel oil were 74,100 kg of CO_2/TJ fuel, 3 kg of CH_4/TJ fuel and 0.6 kg of N_2O/TJ fuel respectively. The low heating value (LHV) of LPG was 47.3 TJ/Gg and that of diesel oil was 43.8 TJ/Gg [10]. Calculations of gas emission from combustion are shown in Eq. (1) and (2) as follows:

$$\text{Gas emission} = \Sigma(AE_{\text{fuel}} \times \text{gas emission factor})/1{,}000{,}000 \quad (1)$$

The AE $_{\text{fuel}}$ refers to the amounts of combustion fuel that are converted to the energy source (TJ/yr) and the AE $_{\text{fuel}}$ can be calculated as follows:

$$AE_{\text{fuel}} = \text{LPG used (kg/yr)} \times \text{LHV (TJ/Gg)} \quad (2)$$

Note: TJ = Terajoule

In this study, evaluation of GHG from water body on the fish farm was applied. Krittayakasem *et al*. [13] proposed that greenhouse gas particularly N_2O was generated regarding the microbial nitrification and de-nitrification processes in the pond system. Therefore, evaluation of GHG emissions from the pond should be possible. However, directly quantifying the GHG emitted from water surface of the pond is challenging due to the complication of the pond ecosystem. Therefore, quantifying the emission of CO_2, N_2O and CH_4 were determined based on a study of [14, 15] which indicated that the emission factors of CO_2, N_2O and CH_4 from aquaculture drained pond were 0.033 $g/m^2/h$, 0.859 $g/m^2/h$ and 0.01 $g/m^2/h$ respectively. The obtained EI from the pond's surface can be calculated by multiplying the surface area (m^2) of each pond by the time spending for culturing the fish and the emission factors of CO_2, N_2O and CH_4.

The process of pond preparation before rearing the milkfish usually uses lime for adjusting the pH of the pond and using pig manure for contribution of nutrient and plankton for fingerlings. Using of lime ($CaCO_3$) for improvement of benthic area in fish pond is a good method for preparation of the soil for nutrient and plankton seeding [16]. Limestone ($CaCO_3$) leads to the emission of CO_2 as carbonate limes dissolve and releases bicarbonate ($2HCO^-_3$) which evolve into CO_2 and H_2O [10]. The tier 1 calculation method following the IPCC guidelines 2006 of CO_2 emission from lime using was applied as shown in the Eq. (3). Then, the obtained value of CO_2-C can be converted to kilogram CO_2 equivalent or kgCO_2 eq. by multiplying 44/12 with CO_2-C value.

$$CO_2\text{-C emission} = \text{M limestone} \times \text{EF limestone} \qquad (3)$$

where M limestone = annual amount of calcic limestone ($CaCO_3$) kg/yr

EF = emission factor, tones of C which is 0.12

Using fertilizer in fish pond before the culture period starts can increase the emissions of GHG [17]. Therefore, evaluation of the GHG emission from fertilizer used is required. The calculation methods of GHGs emission were applied following the methods shown in the studies of Yang *et al.* [15] and Wolter *et al.* [17]. The emission of CO_2, N_2O and CH_4 from using of pig manure in fish pond can be estimated by multiplying the amount of pig manure (kg) that derived from fish farm survey by the average values of emission factors of CO_2, N_2O and CH_4 which were to be 2035.16 kg/dry matter of pig manure, 20.27 kg/dry matter of pig manure and 45.61 kg/dry matter of pig manure respectively [17]. The dry matter of pig manure was derived from [17] which was to be 36.2 % of wet weight of manure.

The low-density polyethylene (LDPE) bag was used for deboned milkfish fillet packaging. The GHGs emissions from LDPE bag were determined based on a study of Siracusa *et al.* [18] which indicated that 1 m^2 of LDPE film emitted 295.73 g of CO_2 and 617 mg of NOx. The EI of CO_2 and NOx from using LDPE bag in this study can be estimated by multiplying the emission factor of each GHG by the area of used LDPE for packaging the deboned milkfish fillet of 0.5 kg. The applied EF of all parameters are shown in Table I.

The EI of GHG from refrigerant was determined based on the United States Environmental Protection Agency guidelines [19]. Estimation of refrigerants emissions was considered only the operating emission of the refrigerators. Determination of emission from installation of new refrigerators and the disposal of the equipment were excluded due to the fact that the refrigerators were already installed and during the intervention process the refrigerators were in use. The EI of fugitive refrigerant can be calculated based on Eq. (4) as follow;

$$\text{Emission of fugitive refrigerant from operation process} = C \times (X/100) \times T \qquad (4)$$

where;

C = refrigerant capacity of the pieces of equipment

X = annual leak rate in percent of capacity

T = Time in year used during the reporting period

In this study, the "T" value used was 1 due to the fact that the data intervention was collected during 1 year of operation.

The obtained calculated value of refrigerant emission can be converted to global warming potential in term of kgCO2 eq. by multiplying the calculated value with the equivalent factor of used refrigerant. In general, the used refrigerant in Thailand is R134a which exhibits the equivalent factor of 1430 [19].

TABLE I: THE APPLIED EMISSION FACTORS (EF) OF GHG IN THIS STUDY

GHG	Sources of emissions	EF	references
CO_2	Shrimp feed	1.29 kg/kg of feed	[11]
	Power supply	589.25 g/kWh	[12]
	LPG	56100 kg of CO_2/TJ fuel	[10]
	Diesel oil	74100 kg of CO_2/ TJ fuel	[10]
	Drainage fish pond	0.033 $g/m^2/h$	[14]
	Lime	0.12	[16]
	Pig manure	2035.16 kg/dry matter pig manure	[17]
	LDPE	295.73 g/1 m^2 LDPE	[18]
NOx	Power supply	1.28 g/ kWh	[12]
	LDPE	617 mg/1 m^2 LDPE	[18]
N_2O	LPG	0.1 kg of N_2O/TJ fuel	[10]
	Diesel oil	0.6 kg of N_2O/TJ fuel	[10]
	Drainage fish pond	0.859 $g/m^2/h$	[14]
	Pig manure	20.27 kg/dry matter pig manure	[17]
CH_4	Shrimp feed	1.29 kg	[11]
	LPG	1 kg of CH_4/TJ fuel	[10]
	Diesel oil	3 kg of CH_4/TJ fuel	[10]
	Drainage fish pond	0.01 $g/m^2/h$	[14]
	Pig manure	45.61 kg/dry matter pig manure	[17]

The GHG emissions from ice using were excluded due to the very low level of ice using. The GHG emissions from waste water of deboning unit was excluded because of the waste water drainage ditches from deboning unit are not separate from the drainage ditches of the buildings.

III. RESULT AND DISCUSSION

A. Inventory Data Results

The 0.5 kg of deboned milkfish fillet (functional unit, FU) derived from two milkfish production units, including the hatchery and the milkfish farm. Regarding to the report of [6], there is the only one organization which is called Prachuap Khiri Khan Coastal Fisheries Research and Development

Centre of Thailand that produces milkfish fingerlings. The 300 mature brood fish were reared in six cylindrical cement tanks with the 11.5 m diameter [6]. The brood stock was fed with commercial fish feed at a ratio of 3% of body weight twice a day. This center extracts seawater from the ditches that is located near the center. Aerators were applied in each tank for aeration for 8 hours/day [6]. In each brood stocks tank, the seawater was drained every other day and the debris and organic matter in the cement tank were removed simultaneously [6]. The spawning process of milkfish started during March–June. After the eggs hatched out, it took 30 days for growth till the stage of fry. The milkfish fry was fed with plankton for 10 days and then they were fed with commercial fish feed. Fingerlings that were available for selling were 3–5 cm long and the average weight of each fingerling was 5.30 ±1.23 g. In one production cycle of milkfish fingerlings in Thailand, around 1,000,000 fingerlings were produced and the farmer came to the Prachuap Khiri Khan Coastal Fisheries Research and Development Centre to buy them and brought them for further rearing [6].

Intensively fingerlings production requires power supply for aeration and water pumping. Fish feeding used in this unit was the commercial catfish feed. However, this study could not identify the amounts of ingredients contained in fish feed. Therefore, the greenhouse gas emission from fish feed production were determined based on the report of Pianjing and Wites [6] which applied a study of Suksathit [11] for the calculation of fish feed GHGs emissions. The GHG emissions of transportation of fish feed to this center was excluded due to the fact that we could not identify the reliable distance of fish feed suppliers [6]. Plankton production unit in the fingerlings production center used liquefied petroleum gas (LPG) for boiling the water for culturing plankton [6]. The data of inputs and out puts of hatchery unit is shown in Table II.

The farmer came to the research center for three times in every two weeks by the 2000 CC pick-up truck and bought around 10,000 milkfish fingerlings. The milkfish farm is located in Kui Buri District which is far from the Center by 70 km. The farm is located near the ditch for easy access to seawater. The stock density of milkfish fingerlings amounted to approximately 3.125 fingerlings/m^2. The culturing area is around 16,000 m^2 and the water surface of the cultured pond was 15,306 m^2 and each pond was approximately 1.5 m deep. For the pond preparation process, after draining the water out and the empty ponds were dry, the farmer used 800 kg of the lime for adjusting the pH of benthic area and the 2000 kg of slurry pig manure were applied at the bottom of the pond as the fertilizer for planktons. The new batch of fingerlings was cultured in net cages in each pond for 30 days and then they were moved to ponds. The milkfish fingerlings were fed with several types of commercial fish feeds. As such, the protein contents in the feed was 35–40% and all of the feeds used were pellet extruded feed. The farmer fed the fish manually and the rate of feed used was 3% of fish weight. It took seven months for culturing the milkfish and the overall fish feed used was 17,100 kg. The average weights of the harvested milkfish were 0.5–0.8 kg. The total amount of 9000 kg of milkfish was harvested and the Feed Conversion Ratio (FCR) was 1.9. The survival rate was around 88% and approximately 8800 caught milkfish as shown in Table II.

Three surface aerators were used for supplying oxygen in each pond and the machines were operated during night time for 10 hours a day. The farmer in the milkfish farm changed the seawater twice a month and discharged 50% of sea water in each pond into the ditch during the low tide. While during the high tide, the farmer used water pumping machines to extract the sea water from the ditch in order to add the new sea water. The mature milkfish were harvested by using the seines. The farmer selected the milkfish at the averaged weight of 0.65 kg/milkfish and collected them for 4500 kg or around 6900 individuals of milkfish in order to send them for the deboning process. The rest of milkfish were sold for the retailers which brought them to sell in the markets.

The farmer used pick-up truck to transport the milkfish to the deboning unit and used ice for preserving the fish freshness. The farmer transported the milkfish to the deboning unit for six times and the average weight of loading in each round was 750 kg or approximately 1,150 milkfish were transported. The electricity consumption and the inputs and outputs data of the milkfish farm were shown in Table II. When the milkfish were harvested, the water in the ponds was drained and the farmer allowed the pond to dry for 1–2 months. After sun drying for 1–2 months, the slurry sediment in the ponds was dredged and the sediment was brought to build the road or the pond dike.

The milkfish from the farm were sent to the deboning unit and they were kept in ice boxes waiting for deboning process. In general, the deboned milkfish procedure is completed within 24 hours in order to avoid the rigor of milkfish flesh and preserve its good texture. Therefore, all the milkfish were deboned after being transported from the farm within 24 hours. The deboning process started by removing scales and washing the fish with fresh water. The anal fins are removed by making a small cut to the large fin and removing the fin bones by the forceps. This process can remove fin bones and small bones in the flesh. The fish is cut at the dorsal side from head to caudal peduncle and then the fish was split out and the butterfly shape appeared. The gill and internal viscera are removed and the vertebra and thorns are removed by knife and forceps. This process consumed five litters of water for washing debris and waste and the 0.65 kg of milkfish produced around 150 g of solid waste. The 0.5 kg of deboned milkfish fillet was packed in LDPE plastic bag and froze in the refrigerators at −20°C. In this study the refrigerators used were classified as domestic refrigeration due to the fact that the level of refrigerants which is R134a in each refrigerator is 100 g [18]. The LDPE used for packing the deboned milkfish fillet was 0.137 m^2.

TABLE II: INPUTS AND OUTPUTS OF THE MILKFISH PRODUCTION SYSTEM OF EACH UNIT

Inputs and outputs	values
Hatchery unit	
Input	
Seawater (million Liter)	25.92
Fish feed (kg)	4404
Electricity (kWh)	28.84
LPG (kg)	120
output	
Fingerlings (No. of produced fingerling)	1,000,000

Milkfish farming	
Inputs	
Seawater (million liters)	475.16
Fingerlings (No. of fingerlings)	10,000
Fish feed (kg)	17,100
FCR	1.9
Electricity (kWh)	0.022
Lime (kg)	800
Pig manure (kg)	2000
Diesel (kg)	165.12
Output	
Harvested milkfish (kg of live weight)	9000
Number of milkfish	8800
Deboning unit	
Inputs	
Fresh milkfish (kg)	4500
Number of milkfish	6900
Fresh water (liter)	34,500
LDPE (12 inch x 15 inch) (No. of bags)	6900
Electricity (kWh)	0.35
Refrigerators (No. of refrigerators)	2
Output	
Solid waste (kg)	1038
Waste water (Liter)	34,500

B. *Greenhouse Gas Emission*

The major source of GHG emitted from hatchery was the electricity used for aerators and water pumping. In this study, the on-farm energy used in the hatchery depended on the rate and time duration of energy using for maintenance of the fragile young fish larvae and water pumping for sea water exchange (Table III). The CO_2 and NOx emissions were mainly derived from these activities. However, fish feed also exhibited CO_2 emissions in a lesser extent. Fish feed ingredients, particularly the soy meal and fish meal, are the major constituents that caused the CO_2 and CH_4 emission. Fish feeding is one of the major sources of GHG emissions [20, 21]. Several studies recommended the substitution of the feed composition with local plant based raw materials as well as the improvement of feed processing in order to reduce the GHG emissions. The ebullition from water surface of the cultured tanks also exhibited significant N_2O and CH_4 emissions. In this study, all cultured tanks are of the open system which influenced the emissions of N_2O and CH_4 from the microbial activities in the sediment [13]. We applied the calculation method of N_2O and CH_4 emissions based on the assumption that the GHG including CO_2, N_2O and CH_4 are directly emitted from the tanks or fish ponds by ebullition. This emission characteristic should not be neglected due to the significant source of GHG concern [15]. The N_2O and CH_4 also exhibit the high global warming potential in term of kgCO_2 eq. the equivalent factors of NO_x and CH_4 in terms of kgCO_2 are 310 and 21 respectively [9]. The obtained calculated values of N_2O and CH_4 were 188.12 g and 2.31 g. as shown in Table II which exhibited the global warming potential at 58.31 kgCO_2 eq. and 0.048 kgCO_2 eq. respectively. These contributed GHG emission values attributed to the fingerlings production and can influence the carbon foot print estimation of the fish product.

The higher source of CO_2 and CH_4 emissions from the milkfish farm was the fish feed as shown in Table III. Milkfish were fed by commercial cat fish feed. The fish feed used in the farm showed only the types of compositions which represented the percentage of protein contents which was 36% on the feed packaging. The FCR rate of the farm indicated the efficiency of fish feed management. Ioakeimidis *et al*. [20] indicated that moderate FCR level (approximately 1.7) was related to the good feeding practice, fish stocking and good water quality whereas the high FCR (approximately 2.1) was related to the poor feeding practice and lower water quality. The milkfish farm exhibited the rather high FCR (approximately 1.9) which means that the farmer needs higher amount of feed for growing their fish that can cause significant GHG emissions. The GHG emissions was attributed to fish feed resulted from the evaluation of emission intensity derived from the raw materials extraction process and processing of feed material [15]. The obtained GHG emission evaluations from this study indicated that this milkfish farm should improve the feeding practice, particularly the improvement of the method in order to improve FCR.

Reducing the N surplus that occurred from poor practical feeding can reduce N_2O releasing from the pond [14]. The appropriate method for reducing the N surplus could be applied in a number of ways, such as decreasing the uneaten feed by closely observing the feed and determine the appropriate N content for the specific fish species. As we already mentioned, there is no specific feed for the milkfish in Thailand. Therefore, development of the feeds that are suitable for fish species should be addressed.

Electricity used in this farm is primarily for aerators and water pumping due to the needing of oxygen supply for a high stock density. The emissions of N_2O and CH_4 from ebullition were higher than the ebullition values from the hatchery unit due to the fact that the farm possessing needs for more areas of large ponds. When the N_2O and CH_4 ebullitions were conversed to be kgCO_2 eq., it was found that N_2O and CH_4 ebullitions exhibited 1484.9 kgCO_2 eq. and 1.22 kgCO_2 eq. respectively. The global warming potential in terms of kgCO_2 eq. from the drainage ponds such as those in the milkfish farm can be significant sources of GHG emissions [14]. The drained ponds also showed higher emissions than the un-drained ponds. The better method for reduction of these emissions was to maintain the water depth in pond [14]. Maintaining the water depth can prevent penetrating of oxygen into the sediment of the pond which can lower the de-nitrification mechanism in the sediment [14]. The de-nitrification process in fish pond sediment needs oxygen supply for the mechanism and can cause the N_2O emission from the pond [15]. The location of the milkfish farm is near the coastal area that is similar to a study of [14] which indicated that fish ponds at the coastal area in China emitted high amount of GHG from ponds ebullition. However, the obtained values of GHG emissions from ebullition were calculated based on Hu *et al.*'s [14] method which was contributed from the area that exhibited a different climate condition from Thailand. Hence, further measurement of N_2O and CH_4 from fish ponds in Thailand should be undertaken due to the difference of climate conditions and rearing methods.

The major transportation activities in the farm occurred from transportations of fish and feed. The CO_2 emission from diesel engine used in transportation was a major GHG emission source. The on-farm gasoline used could not be avoided due to the transportation of necessary goods and service. Therefore, good planning of transportation such as setting the appropriate loading and gathering for all of activities that can be managed in one round of transportation should be considered.

Emissions of GHG from the uses of pig manure and lime showed to be at the rather low level compared to that resulted from electricity using, transportation and ebullition. The GHG emissions from pig manure showed the higher amount of CH_4 which was greater than those of CO_2 and N_2O as shown in Table II. This observed calculated data was similar to the report of Pongpat and Tongpool [22] which remarked that CH_4 emission from liquid state of pig manure was higher than that of N_2O. The microbial activities during the application of pig manure in the bottom part of the ponds deliver nitrogen as ammonia (NH_3) instead of N_2O whereas fermented activities in the slurry condition of pig manure can cause more CH_4 releasing [22].

Utilization of refrigerators for freezing of deboned milkfish was the major source of electricity consumption as shown in Table III. In this study we assumed that the deboned milkfish fillets were frozen in the refrigerators for 24 hours and then they were sold out in each round of deboning. The emissions of CO_2 and NOx from electricity depend on the time of refrigerator's operation. However, this process could not be avoided. Therefore, the use of refrigerators that have good energy efficiency in conservation should be undertaken. The refrigerants leaking from the refrigerators also exhibited the significant amount of CO_2 emission. The refrigerant found in this study was R134a which possesses the global warming potential of 1430 in terms of CO_2 eq. [19]. In this study, we found that the refrigerators contained 100 g of refrigerant [19]. The refrigerators used were classified based on United States Environmental Protection Agency (USEPA) [19] as a domestic type of refrigeration that has the refrigerant capacity of 0.05–0.5 kg and we excluded the installation process and the disposal process. However, the food preservation process badly needs refrigerators for keeping the products until they are sold out. Therefore, using refrigerators cannot be avoided and the best way to reduce the GHG emissions is the prevention of the leakage of refrigerant and using the refrigerators as long as possible.

Emissions of GHG from LDPE are related to the area of the plastic bag [18]. The CO_2 emission attributed to LDPE is derived from the extraction of raw material particularly natural gas and oil [18]. Even though the emission of LDPE in this study showed the rather low level, the use of recycled plastic bags should be suggested [18].

The major solid wastes derived from deboned process were the fish bones and flesh. In this study we found that after the 0.65 kg of milkfish was deboned, it resulted in approximately 150 g of internal viscera, bones and flesh. The spine and small bones were the main components of solid waste following by the removed internal viscera and gills. These wastes were recycled and there was a small amount of discarded solid waste from deboned unit. The bones, fins and flesh were brought to be ground and mixed with milkfish flesh to produce fish burger. The scales were sold to the merchants who brought them to process in cosmetic industry. The removed gills and viscera were sold for fish feeding. The blood and mucus of the milkfish were washed out and the waste water was released to the sewage pipe.

TABLE III: GREENHOUSE GAS EMISSIONS FROM THE DEBONED MILKFISH PRODUCTION PER FUNCTIONAL UNIT (0.5 KG DEBONED MILKFISH FILLET)

Sources of GHG	CO_2 (kg)	NOx , N_2O(g),	CH_4 (g)
Hatchery			
Ebullition from cultural tanks	0.007	188.12	2.31
Electricity	5.26	11.45	-
Fish feed	0.69	-	0.80
LPG	0.038	0.0001	0.0006
Milkfish farm			
Transportation	1.26	0.10	0.05
Ebullition from ponds	0.183	4790.05	58.83
Electricity	1.02	2.224	
Fish feed	1.59	-	2.66
Pig manure	0.0001	0.001	0.004
Lime	0.025	-	-
Deboning unit			
Electricity	4.94	0.01	-
Refrigerant fugitive	1.43	-	-
LDPE	0.04	0.0008	-
Sum	16.47	4991.86	71.88

The data from the Table III reveals that electricity using is the major sources of CO_2 emission. The greater amount of CO_2 emissions from electricity using lead to applying the renewable power supply such as wind power and solar energy or hybrid system in order to reduction of CO_2 emission [23]. Due to the lacking of cat fish feed GHG emission data, the feed production intervention should be addressed as well as identification of feed ingredients, their origin, evaluation of energy use and study on nutrients released from feeding should be included [24]. Moreover, concise methods for quantitative assessment of feeding frequency and the amount of fish feed using in farm should be addressed in order to have the accurate data for GHG emissions [24].

IV. CONCLUSION

Studying the GHG emissions from deboning milkfish process can be a tool for improvement of milkfish rearing and processing. A sustainable aquaculture and fish processing should be initiated for the milkfish processing which can be applied further for development of milkfish aquaculture in Thailand. The significant sources of CO_2 emissions from electricity and fish feed are similar to several studies in Thailand which badly need to improve fish feed production process.

In Thailand, the farmers usually apply cat fish feed or shrimp feed to rear milkfish due to the lack of specific feed formulation for milkfish. In this study, we found that farmers in the coastal area usually apply cat fish feed, Asian sea bass feed and shrimp feed due to the fact that these commercial fish feeds are easily to find in agricultural equipment shops and contain high protein which is good for the growth of fish. Applying unspecific fish feed to rear milkfish may not suitable for fish's growth. Milkfish is a herbivorous fish while cat fish is a carnivorous. Utilization of carnivorous fish feed for herbivorous fish may waste the cost. Therefore, development of specific milkfish feed should be considered.

It should be noted that applying the indirect methods from previous studies for determination of N_2O and CH_4 from pond management can lead to inaccurate data. Therefore, direct assessment of the emissions of N_2O and NH_3 from pond, CH_4 from fertilizer and water evaporation of milkfish farm should be taken into account. Good practice of feeding process, water quality control and maintaining the water depth in the pond can help to reduce the GHG emissions. Application of alternative energy such as wind and solar energy can help to reduce electricity using and the reduction of CO_2 emission will be reduced as a consequence

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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