CARBON MASSFLOW OF THAI NATIVE CHICKEN RAISING AND NILE TILAPIA (*OREOCHROMIS NILOTICUS*) FARMS TO DEVELOP CARBON FOOTPRINTS : A CASE STUDY IN NAKHON RATCHASIMA PROVINCE

Natthakittiya Paiboon

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Environmental Biology

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การถ่ายเทมวลคาร์บอนของการเลี้ยงไก่พื้นเมืองและการทำฟาร์มปลานิล เพื่อพัฒนาค่าคาร์บอนฟุตพรินท์ : กรณีศึกษาจังหวัดนครราชสีมา

นางสาวณัฏฐกิตติยา ไพบูลย์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาชีววิทยาสิ่งแวดล้อม
มหาวิทยาลัยเทคโนโลยีสุรนารี
ปีการศึกษา 2560

CARBON MASSFLOW OF THAI NATIVE CHICKEN RAISING AND NILE TILAPIA (*OREOCHROMIS NILOTICUS*) FARMS TO DEVELOP CARBON FOOTPRINTS : A CASE STUDY IN NAKHON RATCHASIMA PROVINCE

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

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ณัฏฐกิตติยา ไพบูลย์ : การถ่ายเทมวลคาร์บอนของการเลี้ยงไก่พื้นเมืองและการทำฟาร์มปลานิล เพื่อพัฒนาค่าคาร์บอนฟุตพรินท์ : กรณีศึกษาจังหวัดนครราชสีมา (CARBON MASSFLOW OF THAI NATIVE CHICKEN RAISING AND NILE TILAPIA (*OREOCHROMIS NILOTICUS*) FARMS TO DEVELOP CARBON FOOTPRINTS : A CASE STUDY IN NAKHON RATCHASIMA PROVINCE) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.ณัฐวุฒิ ธานี, 148 หน้า

การศึกษาการถ่ายเทและการปลดปล่อยมวลคาร์บอนของการผลิตเนื้อไก่พื้นเมือง และการผลิตปลานิล (*Oreochromis niloticus*) จากการทำฟาร์มเลี้ยงไก่พื้นเมือง และฟาร์มเพาะเลี้ยงปลานิล โดยการประเมินวัฏจักรชีวิต ทำการศึกษาในเขตพื้นที่อำเภอเมืองนครราชสีมา อำเภอขามทะเลสอ อำเภอสูงเนิน และอำเภอปักธงชัย สำหรับไก่พื้นเมือง อำเภอเมืองนครราชสีมา และอำเภอปักธงชัย จังหวัดนครราชสีมา สำหรับปลานิล ระหว่างเดือนตุลาคม 2556 ถึงเดือนกันยายน 2557 มีวัตถุประสงค์เพื่อศึกษาอัตราการถ่ายเทมวลคาร์บอนจากอาหารสัตว์ไปสู่ตัวสัตว์รวมทั้งอัตราการปล่อยคาร์บอนจากการใช้พลังงานไฟฟ้า น้ำมันเชื้อเพลิง และก๊าซปิโตรเลียมเหลวในฟาร์มเลี้ยงสัตว์ โดยการสำรวจและสอบถามข้อมูลจากเกษตรกรเจ้าของฟาร์มเลี้ยงสัตว์โดยตรง พร้อมทั้งได้นำตัวอย่างมาวิเคราะห์หาปริมาณการถ่ายเทมวลคาร์บอนทั้งระบบของการผลิตเนื้อสัตว์ที่ห้องปฏิบัติการ มหาวิทยาลัยเทคโนโลยีสุรนารี

ผลการศึกษาพบว่า การปลดปล่อยก๊าซคาร์บอนไดออกไซด์จากการผลิตไก่พื้นเมืองเท่ากับ 0.016 ± 0.59 กก.คาร์บอน/กก.ไก่พื้นเมือง/วัน และมีประสิทธิภาพในการตรึงคาร์บอนเท่ากับร้อยละ 64.79 ของการปล่อยคาร์บอนทั้งหมด ซึ่งส่วนใหญ่อยู่ในรูปของก๊าซคาร์บอนไดออกไซด์ และก๊าซมีเทน ที่ได้จากการหายใจและการขับถ่าย และพบว่าพลังงานที่ใช้ในการผลิตเนื้อไก่มีค่าปริมาณการปลดปล่อยคาร์บอนเท่ากับ 35.593×10^{-3} กก.คาร์บอน/กก.ไก่พื้นเมือง/วัน ปลานิลมีประสิทธิภาพในการตรึงคาร์บอนมาสะสมประมาณร้อยละ 75 ของการปล่อยคาร์บอนทั้งหมด และอัตราการปล่อยคาร์บอนจากการผลิตตัวปลานิลเท่ากับ 0.0001 ± 0.0001 กก.คาร์บอน/กก.ปลานิล/วัน และอัตราการปล่อยคาร์บอนจากการใช้พลังงานของฟาร์มเลี้ยงปลานิลเท่ากับ 11.6632 กก.คาร์บอน/กก.ปลานิล/วัน จากผลการศึกษาการถ่ายเทมวลคาร์บอนทั้งระบบพบว่ากระบวนการทำฟาร์มเพาะเลี้ยงและการผลิตเนื้อไก่พื้นเมือง และปลานิล สามารถปล่อยคาร์บอนจากฟาร์มเลี้ยงสัตว์สู่สิ่งแวดล้อมได้ ซึ่งส่วนใหญ่เกิดจากการใช้พลังงานภายในฟาร์มเลี้ยงสัตว์และการใช้พลังงานน้ำมันเชื้อเพลิงสำหรับการขนส่ง โดยข้อมูลเหล่านี้สามารถนำไปพัฒนาค่าคาร์บอนฟุตพริ้นท์ของการทำ

ฟาร์มไก่พื้นเมือง และปลานิล ดังนั้นผลการศึกษาครั้งนี้จึงสามารถสรุปได้ว่าระบบการทำฟาร์มเพาะเลี้ยงไก่พื้นเมือง และปลานิล เป็นอีกภาคหนึ่งที่ก่อให้เกิดปัญหาสิ่งแวดล้อมได้

สาขาวิชาชีววิทยา ลายมือชื่อนักศึกษา_______________

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ลายมือชื่ออาจารย์ที่ปรึกษาร่วม_______________

NATTHAKITTIYA PAIBOON : CARBON MASSFLOW OF THAI NATIVE CHICKEN RAISING AND NILE TILAPIA (*OREOCHROMIS NILOTICUS*) FARMS TO DEVELOP CARBON FOOTPRINTS : A CASE STUDY IN NAKHON RATCHASIMA PROVINCE. THESIS ADVISOR : ASST. PROF. NATHAWUT THANEE, Ph.D. 148 PP.

CARBON MASSFLOW/ CARBON EMISSION/ FISHERY PRODUCTION/ LIVESTOCK PRODUCTION/ NILE TILAPIA/ THAI NATIVE CHICKEN

The studies of carbon massflow and carbon emission of livestock and fish using life cycle assessment (LCA) were conducted in Mueang Nakhon Ratchasima, Kham Thale So, Sung Noen and Pak Thong Chai districts for Thai native chicken and in Mueang Nakhon Ratchasima and Pak Thong Chai districts of Nakhon Ratchasima province for Nile tilapia (*Oreochromis niloticus*). The durations of studies were between October 2013 and September 2014. The objectives of this study were to investigate the rate of carbon massflow from animal feed to Thai native chicken and Nile tilapia and carbon emission from the use of energy, fuel and liquified petroleum gas (LPG). Data collections were performed at selected farms and analyses in the laboratory at Suranaree University of Technology.

The results revealed that carbon emission of Thai native chicken production was 0.016 ± 0.59 kg C/kg Thai native chicken/day and efficiency of carbon fixation was 64.79% of overall carbon released. Most of emitted carbon was in form of carbon dioxide (CO_2) and methane (CH_4) which was released from respiration and excretion processes. In addition, the energy used in Thai native chicken meat production released

35.593×10^{-3} kg C/kg Thai native chicken/day. In addition, Nile tilapia fixed carbon was 75% of overall carbon released and the ratio of carbon emitted was 0.0001 ± 0.0001 kg C/kg Nile tilapia/day in fish production. Furthermore, carbon emission from the use of energy in Nile tilapia farms was 11.6632 kg C/kg Nile tilapia/day. Farm management and production in Thai native chicken and Nile tilapia meat productions emitted carbon to environment mainly from the use of energy in the farms and from fuel for transportation. These results can be used as important data for reducing the carbon footprint in Thai native chicken and Nile tilapia productions. It can be concluded that the Thai native chicken and Nile tilapia farm systems are parts of environmental problems.

School of Biology

Academic Year 2017

Student's Signature______________

Advisor's Signature______________

Co-advisor's Signature______________

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Natthakittiya Paiboon

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LISTS OF ABBREVIATIONS

C	=	Carbon content
Cinput or C-input	=	Average carbon content in animal feed and average carbon input from energy consumption
Cfixation or C-fixation	=	Average carbon content which was fixed in animal body
Cemission or C-emission	=	Average carbon emission from energy consumption of animal meat and egg productions
Cemitted or C-emitted	=	Average carbon emitted in the form of animal faeces including CO_2 and CH_4 from faeces, digestion and respiration
Coutput or C-output	=	Average carbon content in the form of animal faeces
FCR	=	Feed conversion ratio is a measure of the amount of feed consume per unit of body weight gain or carcass weight gain
GWP	=	Global warming potential
GHG	=	Greenhouse gas
CO_2	=	Carbon dioxide
CH_4	=	Methane
N_2O	=	Nitrous oxide
NO_X	=	Nitrogen oxide

LIST OF ABBREVIATIONS (Continued)

LPG	=	Liquefied petroleum gas
kWh	=	Kilowatt-hour
Kg	=	Kilogramme
KJ	=	Kilojoule
TNC	=	Thai native chicken
^{o}C	=	Degree Celsius

CHAPTER I

INTRODUCTION

1.1 The subject relevance

A part of global warming problem is caused by livestock and fishery productions which are the sources of carbondioxide (CO_2), nitrogen oxides (NO_x) and methane (CH_4) that are released to the atmosphere (Thanee et al., 2008). These greenhouse gases (GHG) cause the greenhouse effect which negatively affects the Earth's environment. The Intergovernmental Panel on Climate Change (IPCC) in England in 1995 concluded that global climate change has been mainly caused by GHG which most of them have been released from human activities (IPCC, 1995). The Panel predicted that in 2100 the sea level will be raised up about 3 feet higher than the present level and the environment will be changed. Our world will face the serious environmental problems such as the decline of forests, the distribution and increase of pathogens, pollution, heat wave, drought, flood and storm. Livestock farming contributes about 18% of world GHG emission, accounting for 9% of CO_2, 37-50% of CH_4 and 20-70% of nitrous oxide (N_2O) (OECD, 2000; IPCC, 2001; FAO, 2006; IPCC, 2007). The IPCC (2007) suggested that GHG emission must be reduced considerably from their present levels in order to avoid climate change of a magnitude that will have serious negative consequences for the world communities (IPCC, 2007; Stern, 2006).

The demand for livestock and fishery products; largely meat, milk and eggs, are increasing globally. As a result, the world's livestock and fishery sectors are also growing. Livestock production is growing faster than any other agricultural sub-sectors and it is predicted that by 2020, livestock will produce more than half of the total global agricultural output in value terms (Delgado et al., 1999; Upton, 2004). Livestock production in Thailand has been increased considerably especially chicken and ducks for their meat and eggs. Thai native chicken are one of preferred poultry for consumers and producers. However, data on carbon mass flow, carbon emission and carbon footprint in Thai native chicken production are still scanty (Vichairat tanatragul, 2014).

Scientists usually tie their estimates of the GHG emissions responsible for global warming to sources such as land use changes and agriculture including livestock and transportation. The authors of Livestock's Long Shadow took a different approach, aggregating emissions throughout the livestock commodity chain-from feed production, which includes chemical fertilizer production, deforestation for pasture and feed crops and pasture degradation, through animal production or including enteric fermentation and nitrous oxide emissions from manure to the carbon dioxide emitted during processing and transportation of animal products (FAO, 2006).

Livestock and fishery systems in developing countries are characterized by rapid change, driven by factors such as population growth, increasing in the demand for livestock products as incomes rise and urbanization. Climate change is adding to the considerable development challenges posed by these drivers of change. Livestock and fishery systems have often been the subject of substantial public debate because some systems in the process of providing social benefits use large quantities of natural resources and also emitted significant amounts of GHG. Considering that the demand for meat and milk is increasing and that livestock is only one of many sectors that will need to grow to satisfy human demands, more trade-offs in the use of natural resources can be expected (Herrero et al., 2009; Mc Dermott et al., 2010). At a global level, livestock products contribute about 30% of the protein in people's diets, while in industrialized nations this increases to 53%. This study is predicted to increase, with the global production of meat to increase from 229 million tons in 2001 to 465 million tons in 2050 and milk from 580 tons to 1,043 tons in the same period (Steinfeld et al., 2006). In 2006, the inclusion of species contributing to global meat production was 24% from cattle, 31% from poultry, 39% from pigs and 5% from sheep and goats (FAO, 2006).

The previous assessments of the Livestock, Environment and Development Initiative (LEAD) emphasized the livestock sector perspective and analyzed livestock-environment interactions from the perspective of a livestock production system. This updated assessment inverts this approach and starts from an environmental perspective. It attempts to provide an objective assessment of the many diverse livestock environment interactions. Economic, social and public health objectives are of course taken into account so as to reach realistic conclusions. This assessment then outlines a series of potential solutions that can effectively address the negative consequences of livestock and fishery productions (De Haan et al., 1997; Steinfeld et al., 1997; Tantipanatip et al., 2014).

Livestock has a substantial impact on the world's water, land and biodiversity resources and contributes significantly to climate change. Directly and indirectly, through grazing and through feedcrop production, the livestock sector occupies about

30% of the ice-free terrestrial surface on the planet. In many situations, livestock are a major source of land-based pollution, emitting nutrients and organic matter, pathogens and faeces residues into rivers, lakes and coastal seas. Animals and their wastes emit gases, some of which contribute to climate change, as land-use changes caused by demand for feedgrains and grazing land. Livestock shape entire landscapes and their demands on land for pasture and feedcrop production modify and reduce natural habitats (Steinfeld et al., 1997).

In 1995, the United Nations Framework Convention on Climate Change (UNFCCC) member countries began negotiations on a protocol-an international agreement linked to the existing treaty. The text of the so-called Kyoto Protocol was adopted unanimously in 1997; it entered into force on 16 February 2005. The Protocol's major feature is that it has mandatory targets on GHG emissions for those of the world's leading economies that have accepted it. These targets range from 8% below to 10% above the countries' individual 1990 emissions levels "with a view to reducing their overall emissions of such gases by at least 5% below existing 1990 levels in the commitment period 2008 to 2012". In almost all cases-even those set at 10% above 1990 levels-the limits call for significant reductions in currently projected emissions (UNFCCC, 2005). The Kyoto Protocol created a framework of responsibilities and mechanisms to mitigate climate change by reducing the emissions of GHG into the atmosphere. The Protocol stipulates accounting and reporting of GHG emissions and removals, such as energy use, industrial processes, agriculture, waste and net emissions resulting from land use, land-use change and forestry activities (Gavrilova et al., 2010).

Carbon footprint refers to life cycle inventories for all of the inputs and outputs for every stage of processing from forest regeneration (cradle), product processing, building construction, use and final disposal (grave) have been developed (Lippke et al., 2004). Many carbon pools are altered by decisions affecting the management, design, product choice or processing method when analyzed from cradle to grave (Perez-Garcia et al., 2005).

The carbon is an important element of plants, animals and humans. Carbon dioxide, nitrogen oxides and methane from human activities are the most important GHG contributing to global climate change. In Thailand, some researchers have studied regarding GHG emission from livestock to environment. Some researchers reported GHG emitted from pork production, peking duck, ox and goat production in Nakhon Ratchasima province, but none from Thai native chicken and Nile tilapia productions in Thailand (Thanee et al., 2008; Vichairattanatragul et al., 2015). Hence, the carbon budgets of Thai native chicken and Nile tilapia (*Oreochromis niloticus*) productions were studied to determine carbon emitted from farms, to investigate the rate of carbon massflow from plants to chicken and Nile tilapia in food chain, and to study the carbon emission in energy patterns that is used in meat and egg productions.

1.2 The research objectives

The objectives of this study were as follows:

1.2.1 To study the carbon emission coefficient in food production in Thai native chicken raising and Nile tilapia farms.

1.2.2 To study the carbon massflow which was fixed in animal feed and transfer to animals in Thai native chicken raising and Nile tilapia farms.

1.2.3 To study carbon emission from energy in the process of meat and egg productions in Thai native chicken raising and Nile tilapia farms.

1.2.4 To estimate the emission of greenhouse gases, especially CO_2 and CH_4 of meat and egg productions in Thai native chicken raising and Nile tilapia farms.

1.3 The scope and limitation of the study

To meet the objective the study on carbon transfer for food production to develop the carbon emission coefficient from Thai native chicken and Nile tilapia farms to meet the objectives, was conducted in Mueang Nakhon Ratchasima, Kham Thale So, Sung Noen and Pak Thong Chai districts, Nakhon Ratchasima province.

This study was emphasized on types and amount of food consumed. The difference in varieties of animals in the same species were not be considered. They were in mature stages for collecting body parts, meat or eggs. All the farms of Thai native chicken and Nile Tilapia must be registered with Nakhon Ratchasima Provincial Livestock Office and Department of Fisheries Nakhon Ratchasima. The evaluation and analysis were conducted as the systems were in equilibrium stages using carbon massflow concept. The steps of food production and carbon transfer are shown in Figures 1.1 and 1.2 (modified from Keeratiurai et al., 2013; Thanee et al., 2009; Tantipanatip et al., 2014).

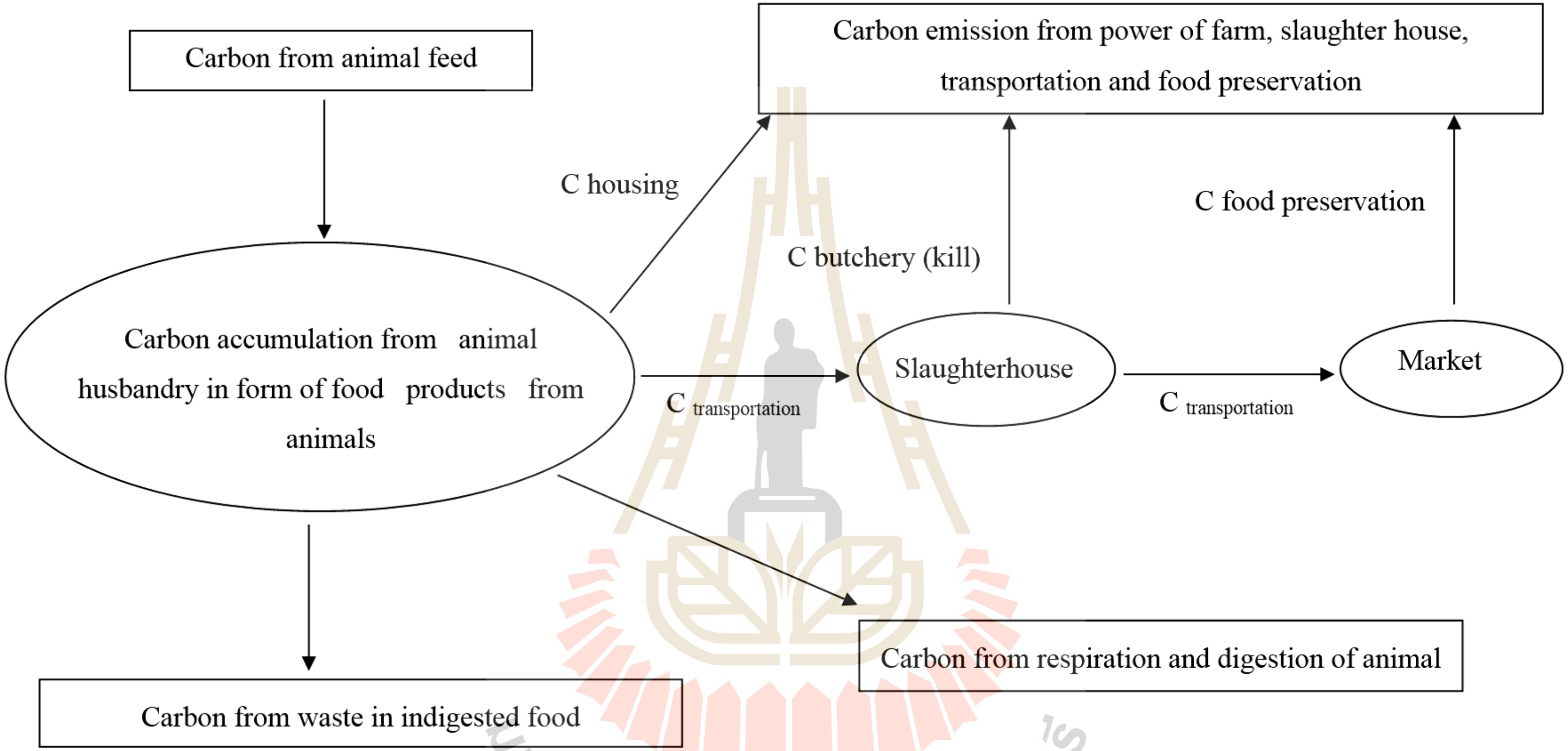

Figure 1.1 Steps of livestock production and relationship of carbon transfer in each step.

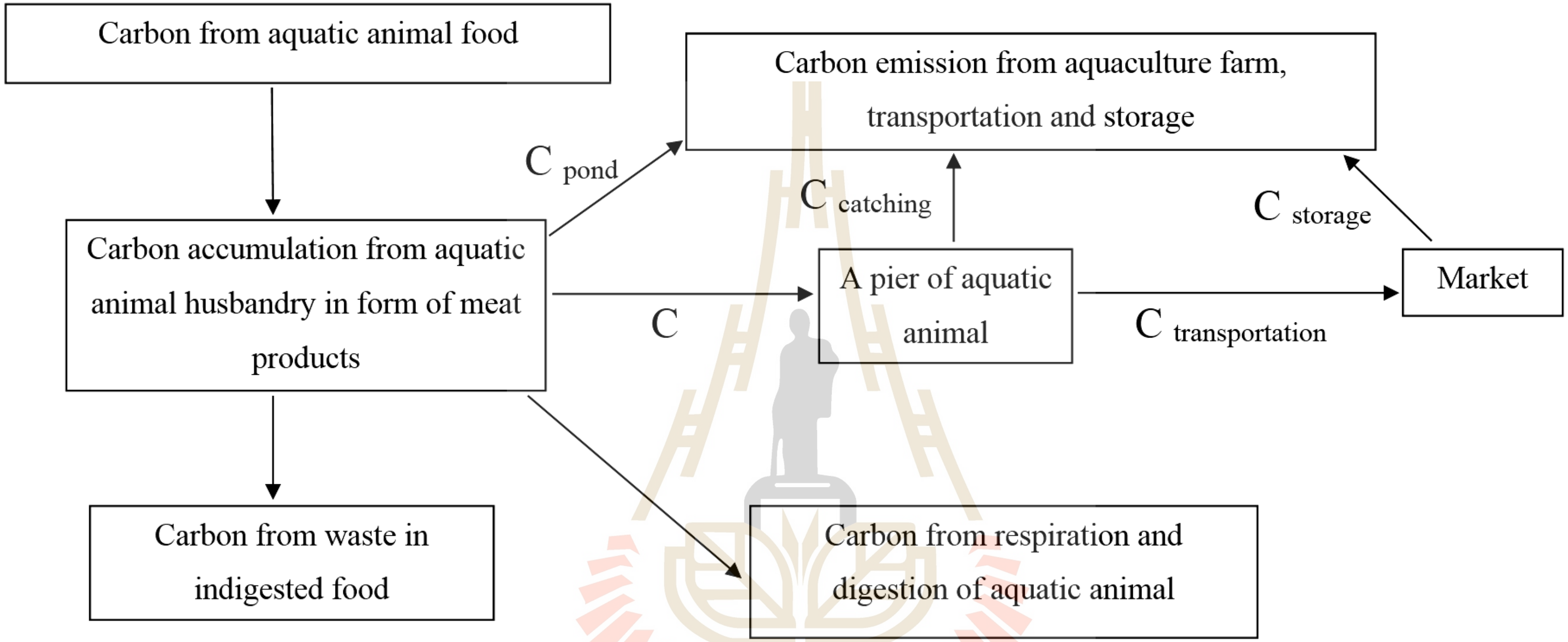

Figure 1.2 Steps of aquatic animal production and relationship of carbon transfer in each step.

CHAPTER II

LITERATURE REVIEW

2.1 Background problem

According to a 2006 report by FAO entitled Livestock's Long Shadow: it stated that livestock production is responsible for 18% of all GHG emissions which is more than all the cars, trains and planes combined. Livestock farming is responsible for 18% of world GHG, including 9% of all CO_2 emissions, 37% of CH_4, and 65% of N_2O which is approximately 296 times more potent than CO_2 as a global warming gas. There are estimated that livestock and fishery breeding require huge water resources and contaminate abyss waters about 4,664 liters of water to produce 1 serving of beef, but entire vegan meat need only 371 liters water. Scientists have calculated that we would actually save more water by indulge one pound of beef, or four hamburgers, than by not showering for at least six months. Moreover, livestock factory is the greatest sector of inappropriate utilization of soil land. Livestock production accounts for 70% of all agricultural land and 30% of the world's surface land area. There are 1 billion people going hungry every day in the world. One-third of the world's cereal harvest and over 90% of soya is used for animal feed despite inherent inefficiencies. Grain currently feed to livestock is enough to feed 2 billion people (FAO, 2006).

The demand for livestock and fishery products; largely meat, milk and eggs, is increasing globally. As a result, the world's livestock and fishery sectors are also growing. This increase puts pressures on the global natural resource base on which the livestock sector ultimately depends. As demand continues to grow, ways need to be found by which livestock and fishery productions can still be increased without damaging the environment which supports that production. An increasing demand for livestock and fishery products poses both challenges and opportunities for the reduction of poverty among poor households that have some potential for livestock and fishery productions (IFAD, 2004; Upton, 2004).

The consumption of livestock and fishery products are growing at a faster rate than the increase in world population. Increasing availability of disposable income, particularly in the developing countries, means that more people can afford the high-value protein that livestock and fishery products offer and which are traditionally seen by society as desirable food items. Increasingly these people are living in towns and cities and over 80% of the world's population growth occurs in the cities of the developing countries. In general, urban populations consume more animal products than those based in rural areas. Human population growth, increasing urbanization and rising incomes are predicted to double the demand for and production of livestock and livestock products in the developing countries over the next 20 years. Livestock production is growing faster than any other agricultural sub-sector and it is predicted that by 2020, livestock will produce more than half of the total global agricultural output in value terms. This process has been referred to as the livestock revolution (Delgado et al., 1999; Tantipanatip et al., 2015).

The fisheries such as Nile tilapia farms are totally dependent on combustion engines and parts of the consumption. The international studies show that several fishery activities have an energy consumption that is far from sustainable. The emissions of GHG along the food chain from hatchery to the consumers are further analyzed to find the dominating sources. It can be concluded that the fishery farming contribute to the GHG emissions. Therefore, the fisheries and aquaculture activities have GHG emission during production operations, transportation, processing and storage of aquatic production. There are significant differences in the emissions associated with the sub-sectors and the species targeted or cultured. The primary mitigation route for energy consumption, through fuel and raw material use, management of distribution, packaging and other supply chain components will be contributed to decreasing the sector of carbon footprint (Tantipanatip et al., 2015).

Increasing the supply of animal products is being achieved by combining an increase in the number of animals with the improvement of productivity and processing/marketing efficiency. Land availability limits the expansion of livestock and fishery numbers in extensive production systems in most regions and the bulk of the increase in livestock and fishery productions will come from increased productivity through intensification and a wider adoption of existing and new production and marketing technologies. While partly driven by demand resulting from population growth, income growth and rising urbanization, there are also changes on the supply side. The spread of technology in the intensive livestock sub-sector has resulted in efficiency gains and prices for livestock and fishery products have generally declined more than prices for food or feed grains. Per capita food consumption of animal products continues to increase both in the developing and industrialized countries, as well as in countries in transition, driven by increased incomes. Changes are also occurring in the type of food consumed. With increasing incomes, there is also increasing demand for greater variety and for greater value and better quality foods such as meat, eggs and milk. The latter is at the expense of food of plant origin such as cereals. These changes in consumption, together with sizeable population growth and urbanization, have led and will continue to lead to increases in the total demand for animal products in many developing countries (Owen et al., 2005).

2.2 Ecosystems and system relationship

Ecosystems are made up of living things (biotic factors) and non-living things (abiotic factors) that interact with each other. Organisms such as bacteria, worms, birds, plants and snakes are examples of biotic factors. Examples of abiotic factors include water, temperature, pH, salinity and light intensity. Within an ecosystem, there are interactions between the biotic factors and between the biotic and abiotic factors. The biotic and abiotic exchange energy and materials. Populations are the subsystems through which the system functions. The relationship between biotic and abiotic components leads to the ecosystem equilibrium (Odum, 1971 and Burrows, 2014).

2.3 Carbon cycle in ecosystems

The carbon cycle: the carbon massflow between organisms are occurring of the process photosynthesis, respiration and digestion. In addition, there is the combustion of fuel and decay of limestone, as shown in Figure 2.1 that releases CO_2 into the atmosphere and has caused greenhouse effects around the world (Smith, 1974).

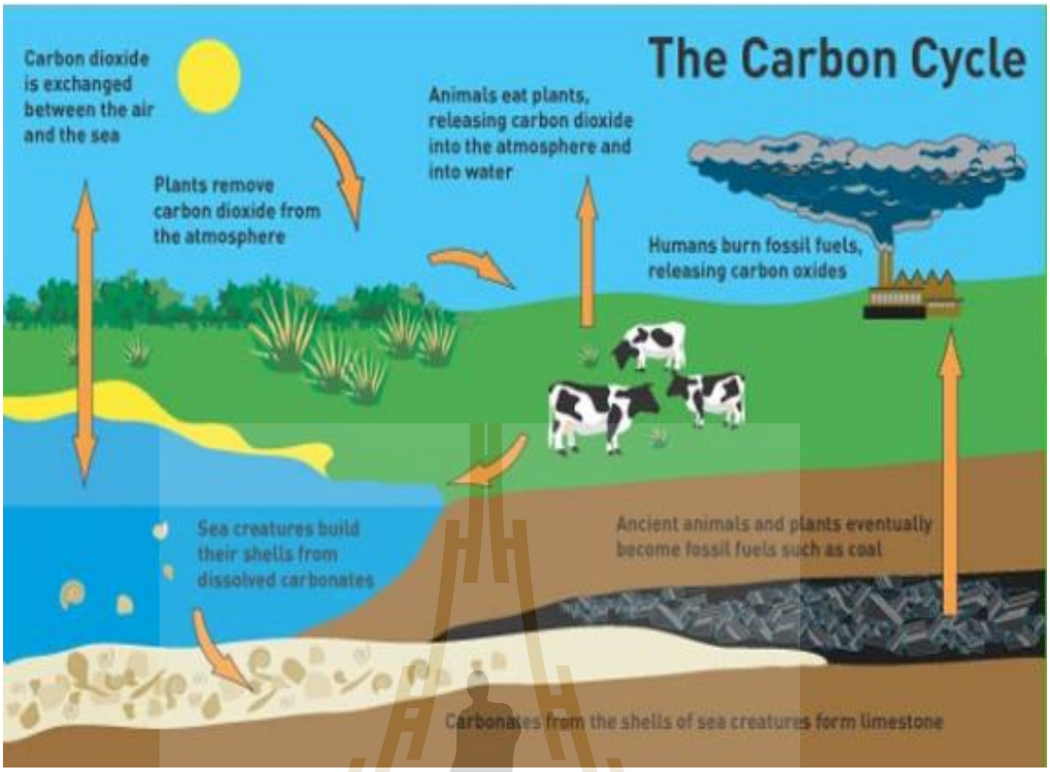

Figure 2.1 The carbon massflow in the ecosystem through the photosynthesis, respiration, decomposition and burning of fuel (Smith, 1974).

The oceans have around 36,000 gigatonnes of carbon, mostly in form of carbonate or bicarbonate ion. The inorganic carbon is important in its reactions within the water. This carbon exchange becomes important in controlling pH in the ocean and can also vary as a source for carbon. The carbon has readily exchanged between the atmosphere and the ocean, which has participate of reactions are locally in equilibrium:

Solution = CO_2 (atmospheric) $\rightleftharpoons$ CO_2 (dissolved)

Conversion to carbonic acid = CO_2 (dissolved) + H_2O $\rightleftharpoons$ H_2CO_3

First ionization = H_2CO_3 $\rightleftharpoons$ H^+ + HCO_3^- (bicarbonate ion)

Second ionization = HCO_3^- $\rightleftharpoons$ H^+ + CO_3^{2-} (carbonate ion)

The CO_2 and other atmospheric gases (e.g. nitrogen and the inert gases) are dissolved in surface waters. Dissolved gases are in equilibrium with the gas in the atmosphere. The CO_2 is reacted with water in solution to form the weak acid and carbonic acid. The carbonic acid dissociates are hydrogen ions and bicarbonate ions. The hydrogen ions and water are reacted with most common minerals (silicates and carbonates) altering the minerals. The products of weathering are predominantly clays (a group of silicate minerals), and soluble ions such as calcium, iron, sodium, and potassium. The bicarbonate ions also remain in solution.

In addition, CO_2 has dissolved into water and different concentrations occur at the various temperatures, as listed in Table 2.1. This information indicator that the amount of CO_2 in water is inversely proportional with water temperature (Boyd, 1955).

Table 2.1 The concentrations of dissolved CO_2 in water at various temperatures.

Temperature (°C)	**Dissolved CO_2 (mg/l)**
0	1.10
5	0.91
10	0.76
15	0.65
20	0.56
25	0.48
30	0.42

Source: Boyd, 1995.

2.4 Animal production and pollution

The main environmental impacts of livestock and fishery production are on soil, water, air, flora, fauna and non-renewable resources. Soil features are affected by nutrient contamination, by trampling and by erosion. Groundwater can be polluted with nitrates and pesticides. Surface water may be threatened by eutrophication. Toxic residues in food are also a threat to human health. Air pollution has an impact on habitats and on global climate change (FAO, 2006).

2.4.1 Animal production and environment interaction

The nature of animal production and environment interactions is dictated mostly by the type of production systems. These production systems are themselves evolving in response to population pressure, resource availability, social and economic forces and importantly-marketing opportunities and constraints. Three main production systems are distinguished although in practice there is a gradual change from grazing through mixed to industrial systems (Sere and Steinfeld, 1996).

Grazing

Grazing systems are mainly based on native grassland and browse, with no or only limited integration with crops. These systems rarely involve imported inputs and generally have a low calorific output per hectare. Grazing systems, particular those on communal land, are affected by changes to traditional grazing rights and an increase in cultivation, with a move towards open access grazing in the remaining areas. The poor sustainability of these systems is shown by declining livestock productivity on a per human capita basis. This is a concern in arid and semi-arid areas of Sub-Saharan Africa, India and Central Asia (Sere and Steinfeld, 1996).

Mixed farming

In mixed farming systems, livestock, fishery and crop activities are integrated. Mixed farming reduces risks from single crop or livestock production, enables more efficient use of labour, and adds value to low value or surplus feed. Mixed farming systems allow the use of waste products of one enterprise (e.g. crop by-products, manure) as inputs to the other enterprise (as feed or fertilizer). Mixed farming is, in principle, beneficial for land quality in terms of maintaining soil fertility. In addition, the use of rotations between various crops and forage legumes replenishes soil nutrients and reduces soil erosion. Mixed crop-livestock systems are ideally in an equilibrium situation. Problems develop where this equilibrium is disturbed as a result of livestock and other products being removed from the system. This causes soil nutrient and energy deficits. Alternatively, an increased reliance on outside inputs (feed and chemical fertilizer) results in nutrient surpluses that exceed the capacity of the land, primarily plants and soil micro-organisms, to deal with it(Sere and Steinfeld, 1996).

Industrial systems

Industrial production systems are detached from immediate land interms of feed supply and waste disposal. Where the demand for animal products increases rapidly, land-based systems fail to respond and lead to animal concentrations which are out of balance with the waste absorptive and feed supply capacity of the land. Industrial production systems are, however, very much tied to land situated elsewhere. This remote land provides feed resources, much of it in the form of grain for example, which may be transported over great distances (Sere and Steinfeld, 1996).

2.4.2 Nutrient balance

Mixed farming systems in general do not add new nutrients to the system. Instead, with constant and long-term removal of products, both crops and livestock, there is in many cases a net reduction in nutrients. The key to sustainable agricultural production is the maintenance of nutrient balance. The most mixed farming systems of the developing world have a negative nutrient balance. Deficits are partially covered by a flow of nutrients from grazing areas to cropland. As population pressure increases, the crop/grazing land ratio changes, with more land being taken up by crops-leaving smaller areas for extensive livestock grazing. If other sources of nutrients are not available, the problem of nutrient balance increases. This is typically the case with many mixed farming systems in the tropics (Steinfeld et al., 1997).

Because of transport costs and market infrastructure, industrial livestock and fishery production systems are normally found close to urban areas. They imported feeds from outside the system and produces large quantities of manure and other wastes-leading to excessive nutrient imbalances. The unbalance systems in some countries, for example the Netherlands with excessive nitrogen surplus mostly resulting from mineral fertilizers and imported feed, with only 16% being removed in the form of livestock products. The remainder represents a potential source of environmental pollution. The opposite case is represented by an example from Southern Mali, where farmers effectively derive a large part of their income from soil nutrient depletion or soil mining. Manure management should aim at reducing the negative effects (lower nutrient losses) and maximizing the positive effects (plant nutrient supply and organic matter supply to the soil) of manure. A more balanced nutrient management will result with the less burden on the environment (Brandjes et al., 1996; Verheijen et al., 1996).

2.4.3 Increasing intensification

Expansion of agricultural areas and intensification are two ways to increase agricultural output in order to meet the demands of an increasing human population. An expansion of areas given over to growing crops inevitably introduces the possibility of conflict with the land requirements for keeping livestock-resulting in an overall loss of available grazing land. At the same time, there is an increase in the demand for livestock and fishery products and the consumption of livestock and fishery products is currently growing at a faster rate than the increase in world population. The greater part of the increase in livestock production and fishery production has come from and will continue to come from increased productivity through intensification. Industrial-scale livestock production arises where the demand for animal products increases too rapidly for land-based systems to respond. Initially the process ID from more extensive systems, through more intensive mixed farming systems and ultimately to industrial-scale livestock production where production is divorced from the surrounding land (Delgado et al., 1999).

The process of intensification is complex, but tied closely to urbanization. As incomes rise, particularly in urban areas, consumers seek greater variety in their diets. Demand for livestock and fishery products increases rapidly, an effect which is driven by the rapid growth in per capita incomes, particularly in East and South East Asia. At the same time population growth has led to increases in the number of consumers, particularly in urban zones. The high rates of growth in meat supply and consumption, per capita recorded in all regions except North Africa and the Near

East, are significant and form the basis of the so-called “Livestock Revolution”. If the growth in consumer demand continues at the same rate, livestock producers are faced with rapidly expanding urban markets (Delgado et al., 1999).

The rapid changes in supply and consumption of meat are accompanied by shifts in the types of meat contributing to the total. Over the past ten years, while consumption per head of cattle, poultry and fish meat has remained more or less steady in all regions of the developing world (with the exception of Latin America where beef consumption rose by 1% annually), poultry meat consumption has risen annually by over 6.5% in South Asia, and by nearly 6% in Latin America. Significant increases in consumption of eggs are also recorded for all regions except Africa. Hence, it can be argued that the rapid increases in consumption of livestock and fishery products have largely stemmed from a shift towards consumption of poultry products (Misra,1996; Misra et al., 2003).

2.4.4 Waste product

Industrial livestock and fishery production systems emit large quantities of waste, resulting in excessive loading of manure on the limited land areas within reasonable distances of the production facilities. Globally, estimated that swine and poultry industries produce 6.9 million tons of nitrogen per year, equivalent to 7% of the total inorganic nitrogen fertilizer production in the world. In these areas of high animal concentrations, excess nitrogen and phosphorus leaches or runs off into drainage and groundwater, damaging aquatic and wetland ecosystems and polluting water supplies for human consumption (Steinfeld et al., 1997).

The return of nutrients to the land by the application of manure causes problems due to high water content and high transport cost. While it is difficult to generalize, transport beyond 15 kilometers is often uneconomical. In addition, mineral fertilizers, often a cheaper, more available and more practical source of nutrients, further reduce the demand for nutrients from manure, turning the latter into “waste”. These nutrient surplus situations also result in high concentrations of heavy metals. These are contained in livestock and fishery feed as growth stimulants (e.g. copper and zinc), or simply as pollutants (e.g. cadmium). If the addition to the soil of heavy metals exceeds uptake by crops, this will most likely have a negative impact on soil flora and fauna, eventually leading to human and animal health risks (Bos and de Wit, 1996). Regulations to reduce the heavy metal content of animal feed are now in place in most OECD member countries. An absence of regulations in many developing countries is likely to result in problems in the future.

Drainage of manure and other animal wastes into surface water and leaching from saturated soils is now a feature closely associated with industrial livestock and fishery production systems. In areas with high livestock concentrations (e.g. in the Netherlands, Australia, South East Asia and East Asia) the spreading of manure on land leads to nitrogen leaching into water. Nitrates contaminate surface waters, leading to high algal growth, eutrophication and subsequent damage to the aquatic and wetland ecosystems. Phosphates, although less mobile than nitrates, cause similar problems (Steinfeld et al., 1997).

Nitrate is a potential human health threat especially to infants, causing the condition known as methaemoglobinaemia, also called “blue baby syndrome”. Nitrate is converted in the gut to nitrite, which then combines with hemoglobin to form methaemoglobin, thus decreasing the ability of the blood to carry oxygen. Removal of these and other agricultural pollutants from water sources intended for human consumption is expensive. Moreover, it is not normally the polluter that pays for this resulting in artificial subsidies for those industrial livestock production systems causing some of the greatest pollution problems. For example, approximately 70-80% of the UK's nitrate input to the water environment comes from diffuse sources, with agricultural land as the main source. It is only recently that the scale of the costs involved has begun to be appreciated (Pretty et al., 2000), for example, estimated the total external environmental costs of agriculture in the UK was £2.3 billion in 1996. The approximate annual costs of treating drinking water for pesticides were about £120 million, for phosphate and soil £55 million, for nitrates £16 million and for micro-organisms £23 million. Monitoring water supplies and supplying advice on pesticides and nutrients costs were around £11 million and off- site damage from soil erosion was put at £14 million (Steinfeld et al., 1997).

2.4.5 Processing and slaughterhouse wastes

As well as manure and other waste from animal production, the processing of animal products also results in environmental damage when it is concentrated and unregulated. This is particularly the case in urban and peri-urban environments in many developing countries. Slaughtering requires large amounts of hot water and steam for sterilization and cleaning and the resulting wastewater is the main cause of pollution. A concentration of organic compounds in wastewater leads to a biological oxygen demand (BOD). Wastewater includes fat, oil, proteins, carbohydrates and other biodegradable compounds and breakdown of these substances requires oxygen. Wastewater usually contains additional insoluble organic and inorganic particles or suspended solids. Effluent from tanneries may be discharged into sewers, or into inland surface waters, or even used for irrigation. High concentrations of salt and hydrogen sulphide present in tannery wastewater have a negative impact on water quality. Suspended matter such as lime, hair, flashings, etc. make the surface water turbid and settle to the bottom, thereby affecting fish. Chromium tannin is toxic to fish and other aquatic life. When mineral tannery wastewater is applied on the land, the soil productivity is adversely affected and some part of the land may become completely infertile. Due to infiltration, ground waters are also adversely affected (Verheijen et al., 1996). Discharge from dairies is often an issue in the developd world where the most milk is processed at an industrial scale. In developing countries, homes or villages processing or consumption of processed milk is much more common. In Africa, it is estimated that 80 - 90% of milk is home processed or consumed raw whereas for Latin America, this share averages about 50% (FAO, 1990). Again, wastewater production from milk processing is the major environmental concern, mainly resulting from cleaning operations. In principle, the production of wastewater does not necessarily lead to environmental problems if animal product processing is carried out on a small scale and is not concentrated in a given area (FAO, 2006; Tammiga, 2003).

2.5 Changed pressures on the livestock and fishery sector

The increasing demand for livestock and fishery products is an important driving force resulting in changing pressures within the livestock and fishery sectors. These modified pressures induce responses by the livestock and fishery sectors and a number of general changes or shifts in state can be observed:

2.5.1 Changed functions and/or species:

- From non food to food functions.

- From multipurpose to single purpose livestock production (e.g. utility chickens to Thai native chicken).

- From ruminant to non-ruminants (e.g. moves towards pigs and poultry).

2.5.2 Geographical shifts:

- From marginal areas to humid and sub-humid zones.

- From rural areas to urban areas.

2.5.3 Structural and technological shifts:

- From resource-driven to demand driven livestock and fishery productions.

- From small scale to large scale (economies of scale and industrial production).

- From horizontal to vertical integration.

- From low input to high input livestock production (Fleischhauer et al., 1997; OECD, 1997; OECD, 1999).

2.6 Environmental impacts from livestock production

About one quarter of the world's total land area is used for grazing livestock. In addition, about one fifth of the world's arable land is used for growing cereals for livestock feed. Livestock production is the world's largest land user and may soon be its most important agricultural activity in terms of economic output. This change is accompanied by a large number of potential environmental threats. However, it is not the animals who are the culprits. Livestock do not destroy the environment, people do (Vichairattanatragul, 2014 and Tantipanatip, 2014).

Individual livestock owners, particularly in developing countries have in many cases very few options. It is up to policy makers to ensure that the options available to poor livestock keepers and to the industrial scale livestock keepers, are environmentally sound. Uninformed policies are responsible for environmental degradation. The following list provides examples where livestock and environment interactions are particularly critical:

2.6.1 Overgrazing and degradation of grazing lands

This occurs mainly in the zones between grazing areas and cropping areas. The pure grazing areas of the arid and semi-arid zones show a much greater potential for resilience than expected and are less vulnerable to permanent degradation than the grazing lands which are accessed both by pastoralists as well as livestock keeping crop farmers.

2.6.2 Deforestation

Deforestation for livestock purposes is relevant mainly in Latin America. The causes are complex and are often the result of policy distortion and less by livestock production in the narrow sense. Deforestation in Asia and Africa is mainly due to expansion of cropping area and plantation crops.

2.6.3 Wildlife and livestock interactions

Often, in particular in Africa, livestock and wildlife are grazing the same lands and a large part of wildlife is living outside the protected areas. The traditional park idea without livestock inside the parks is unimaginative. This is the non-sharing of profits from tourism with the local population leads to conflicts.

2.6.4 Upsetting the balance between crops and livestock

The balance between crops and livestock can easily be upset, leading to land degradation. In many highland areas of the tropics, high human population densities have been sustained by complex farming systems, As each generation needs land, farm sizes become smaller and smaller until a point is reached where the system collapses.

2.6.5 Soil and water pollution

Because of soil and water pollution are excess nutrients in industrial livestock productions. Industrial production can create enormous pollution problems because it brings in large quantities of nutrients in form of concentrate feed and then has to dispose of the manure to nearby land which quickly becomes saturated. As a result, land and groundwater are polluted.

2.6.6 Climate change

Greenhouse gases (GHG) contributing to global warming. Greenhouse gases, of which about 5 - 10% is produced by livestock and livestock waste, contribute to global warming.

2.6.7 Nutrient imbalances

Feed production areas are not directly linked with livestock feed use, leading to a transfer of nutrients from feed producing areas to areas with high livestock concentration. On the one hand there is a nutrient deficit (this can be thought of a mining the nutrients) and on the other hand there is nutrient surplus which leads to pollution.

2.6.8 Reduction of domestic animal diversity

Industrial livestock production in particular and also livestock production in mixed systems use a very limited range of animal breeds. This has already led to the extinction of some local livestock breeds and the genetic erosion of others. Specific genetically determined capacities in local breeds to cope with the climatic, nutritional and disease challenge may already have been lost.

2.6.9 Disease transmission

The widespread use of antibiotics, not only to prevent or cure diseases but also to promote animal growth, leads to the development of resistant bacteria and germs and may jeopardize the possibilities to use antibiotics to cure infections in humans. This is a particular risk in intensive, industrial systems of animal production. Also new diseases, such as BSE and the increasing salmonella infections of food are mainly linked to industrial systems (Fleischhauer et al., 1997).

2.7 Development options

A multi donor initiative has identified a number of major potentials to improve the situation exist in the following areas of intervention:

- Provision and dissemination of up to date information on livestock and environment interactions.

- Development of livestock production technologies which, by satisfy the demand for livestock products, whilst at the same time focus on livestock and environment interactions.

- The scope for increasing livestock production, while simultaneously reducing the use of natural resources per unit of products, is still considerable and has to be further exploited. Here research and development will have to play a major role and it will be essential to improve the sharing of technology innovation among all concerned (Vichairattanatragul, 2014 and Tantipanatip, 2014).

2.8 Concepts and related researches

2.8.1 Carbon massflow concepts

The calculation for the amount of emission of greenhouse gasses (GHG) is as follow:

GHG Emission = CO_2 from energy consumption + CO_2 from destroyed forest + CH_4 from rice plantation + CH_4 from livestock (1)

and then ton-carbon unit is changed to ton-CO_2 by multiply by 3.667 (3.667 is the ratio of the CO_2 molecular mass divided by the C molecular mass)

Amount of CH_4 emission from livestock (ton equivalent to CO_2)
= rate of CH_4 emission of each animal species multiply by number of livestock (swine, goats, Thai native chicken and Nile tilapai) (2)

and then change ton-methane to ton-CO_2 by multiply by 21: Radiative forcing

CO_2 emission rate = number of animal multiply by carbon emission factor/unit (3)

(Office of Natural Resources and Environmental Policy and Planning, 1996).

The carbon emission or total carbon from livestock farm using the "principle of mass conservation" which can be applied for this study by calculating total carbon emission in term of weight of carbon per individual (average weight of killed animal such as kilogramme carbon per individual) or weight of carbon per area in each habitat use for animal rearing in average rearing period (such as kilogramme carbon per square meter) as shown in Figure 2.2 and the formula can be:

$$E_{total} = E_{metabolic} + E_{grazing} + E_{housing} + E_{storage} + E_{spreeding} \quad (4)$$

Where:

E_{total} = total carbon emission (kgC/individual).

$E_{metabolic}$ = carbon in animal in term of meat or meat production (kgC/individual).

$E_{grazing} + E_{housing}$ = carbon from food plants eg. grass and houses.

$E_{storage}$ = carbon of energy for meat products and production (kgC/individual).

$E_{spreeding}$ = carbon in term of faeces (kgC/individual).

$$E_{total} = n_{animal} \times (EF_{metabolic} + EF_{grazing} + EF_{housing} + EF_{storage} + EF_{spreading}) \quad (5)$$

Where:

n = Number of animal (each species, each area).

EF = Carbon emission factors in term of meat products in each species (kgC/individual/area). Calculated from mean weight per individual of killed animal or average time for rearing (UNECE, 2004).

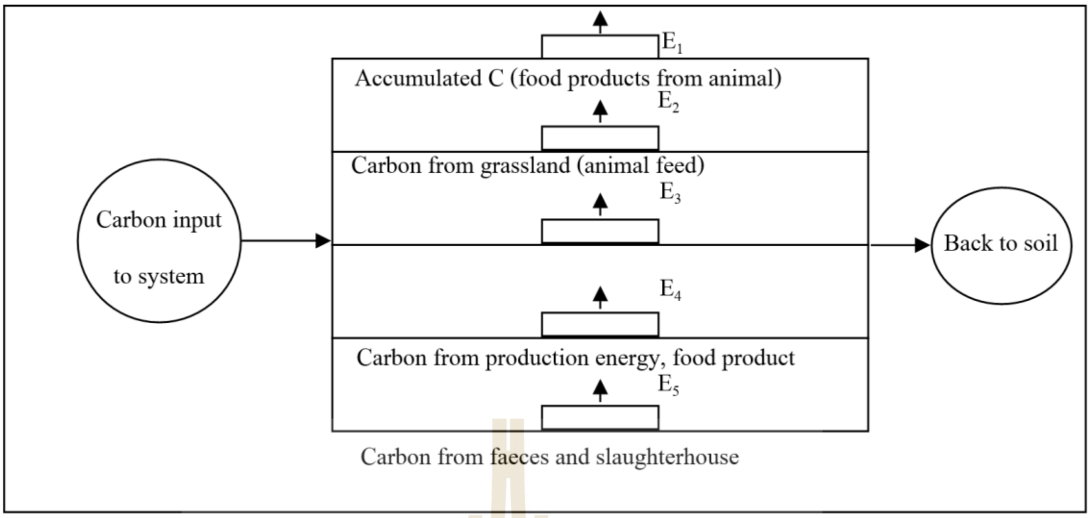

Figure 2.2 Carbon emission systems in each activity of livestock framing (UNECE, 2004).

2.8.2 The impact of animal production on environment and carbon change

The animal productions usually have impacts on the environment such as soil, water and air quality. The impact from animal productions to the atmosphere are also related to the global warming problem, GHG especially CO_2, CH_4 and N_2O which are the main problems (Tammiga, 2003). However, CO_2 emission is usually from fuel used in agricultural activity and little from livestock (less than 5%). It is an important problem because CO_2 from livestock and fishery is at high levels. Methane (CH_4) emission is always from anaerobic digestion of livestock (Sauerbeck, 2001).

Some studies also explain the methods for accounting the carbon from plants that animals eat and release with their faeces (Ickowicz et al., 1999) and faeces indices will be used to account for the use of organic carbon (organic matter intake, OMIJ) and from the organic carbon concentration that released with faeces (faecal organic matter excretion (FOME)) (Guerin et al., 1989). Carbon concentration from faeces is studied by oven drying it at 550°C and then the chromatography method will be used (Thermoques NC Soil 200). The use of carbon in animal production that take to animals in farm will be assumed as the animals get some food and/or get all of biomass only by eating. Although, the carbon intake will be accounted with the average of carbon concentration in all types of animal feed.

The calculated dry matter intake (DMIJ) will be modified from OMIJ and assumed that the ash at 10% of all carbon intake or take to the grow up by starting rearing calculation from birth to the slaughterhouse (Manlay et al., 2002).

The measured gases from animal breathing in cattle by using animal mask. In addition, in Thailand, at Khon Kaen province, the Research Station of Animal Feed in cooperation with JIRCAS since 1994 and they have conducted research project and measured the breath of cows and buffalo by using a mask cover on the animal faces (respiration trial system). This method can measure approximately 93.3% all of gases concentration with 0.8 - 1.7% standard deviation (Kawashima et al., 2000; Liang et al., 1989).

2.8.3 Cost of carbon and greenhouse gases sources

It is note that carbohydrate release 78% CO_2 and 27% CH_4. While, fat release about 52% CO_2 and 48% CH_4 and protein release 73% CO_2 and 27% CH_4. Total organic gases that released from these nutrients are 0.75, 1.44, and 0.98 m^3/kg of dry weight, respectively (Buswell and Hueller, 1952).

The organic gases can be used as renewable energy instead of fuel from firewood, coal, oil, cocking gases and electricity. The use of 1 cubic meter of organic gases can be used for:

1. Heat value of 3,000 - 5,000 kg Cal, can boil 130 kg of water.

2. Produce electricity at 1.8 units (kw-hr).

3. Equivalent with diesel 0.6 liter or benzene 0.67 liter.

4. Can use for cooking that equivalent with cooking gases (LPG) 0.46 kg or firewood 1.5 kg.

5. Use as fuel oil by using 1 m^3 of organic gases as using fuel oil of 0.5 liters (Casey, 1981).

The organic gases from anaerobic system can produce many gases for example, 70% CH_4, 30% CO_2 and a few of other gases. Production volumes depend on the volume of organic materials and these gases can be used for electricity production (Udomsinrote, 2000).

CHAPTER III

MATERIALS AND METHODS

3.1 Selected areas and selected animals

Nakhon Ratchasima or "Korat" is the largest province, situates in the northeastern plateau in Thailand and has an area of around 20,494 square kilometres (7,913 sq mi). Nakhon Ratchasima province was selected as study area. Thai native chicken and Nile tilapia have been raised in Korat based on the data of Nakhon Ratchasima Provincial Livestock Office and Department of Fisheries Nakhon Ratchasima. The selected districts of Nakhon Ratchasima province were Mueang Nakhon Ratchasima, Kham Thale So, Sung Noen and Pak Thong Chai (Department of Livestock Development, 2009, Maps of world, 2015; Nakhonratchasima Provincial Livestock Office, 2013; Fishery Office in Nakhon Ratchasima, 2015). The study areas are shown in Figures 3.1 and 3.2 and Table 3.1.

The study beed of Thai native chicken such as White Tail-yellow Cock or Kai Lueng Hang Khao, Kai Pradu hang dum, Kai chee etc. And Thai native chicken production in Nahkon Ratchasima province there are two models were traditional production and manufacturing system and this study selected data from both system. The collection of Nile Tilapia in the study area, the farmers cultivated the tilapia in the pond and in cage. The study was divided Nile tilapia farms into 3 groups as follows: using area less than 1 rai, used the culture area of 1 - 5 rais and using more than 5 rais.

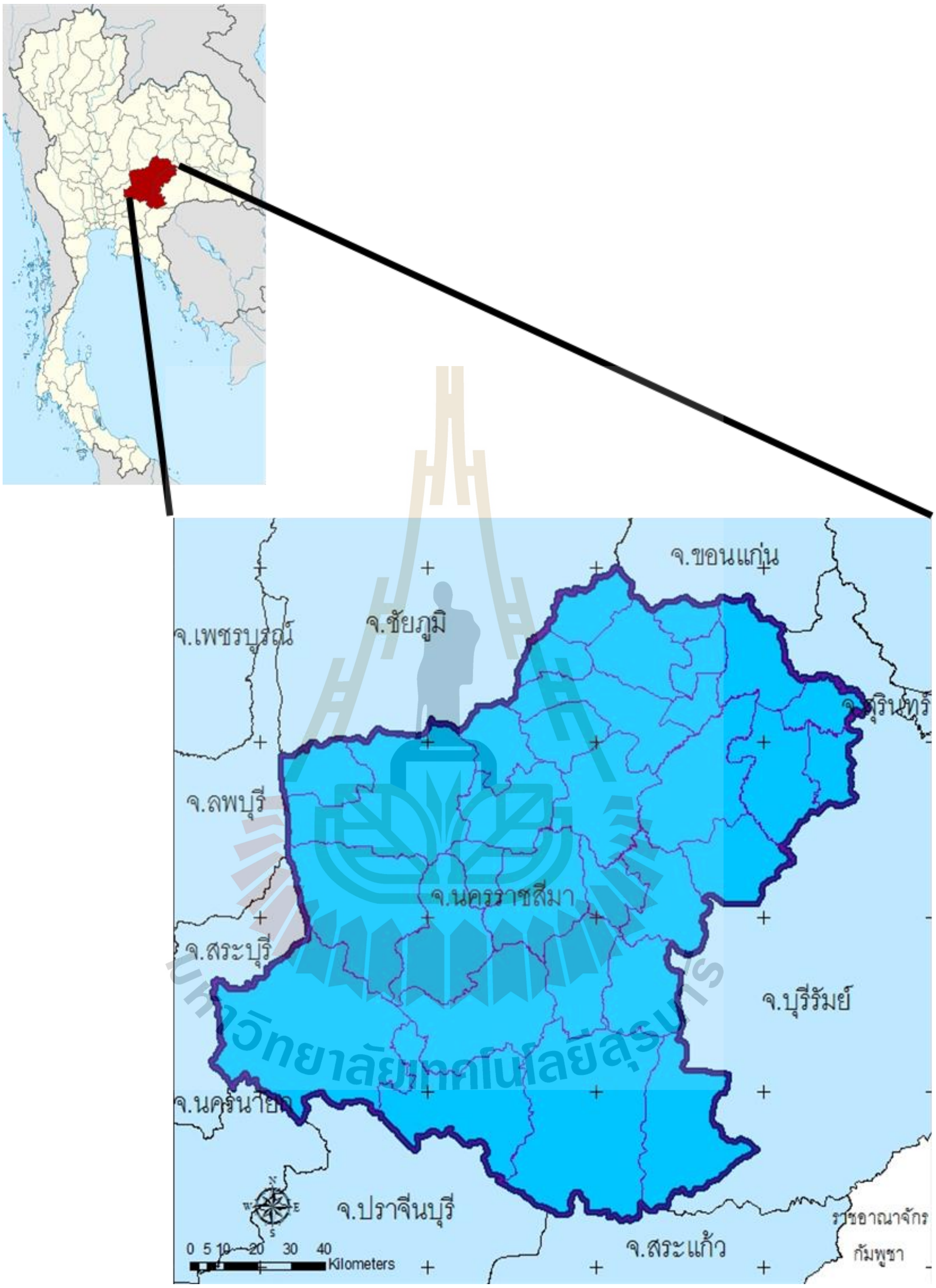

Figure 3.1 The study sites: Nakhon Ratchasima province.

(http://www.mapsofworld.com/thailand/provinces/nakhonratchasima-map.html, 2015)

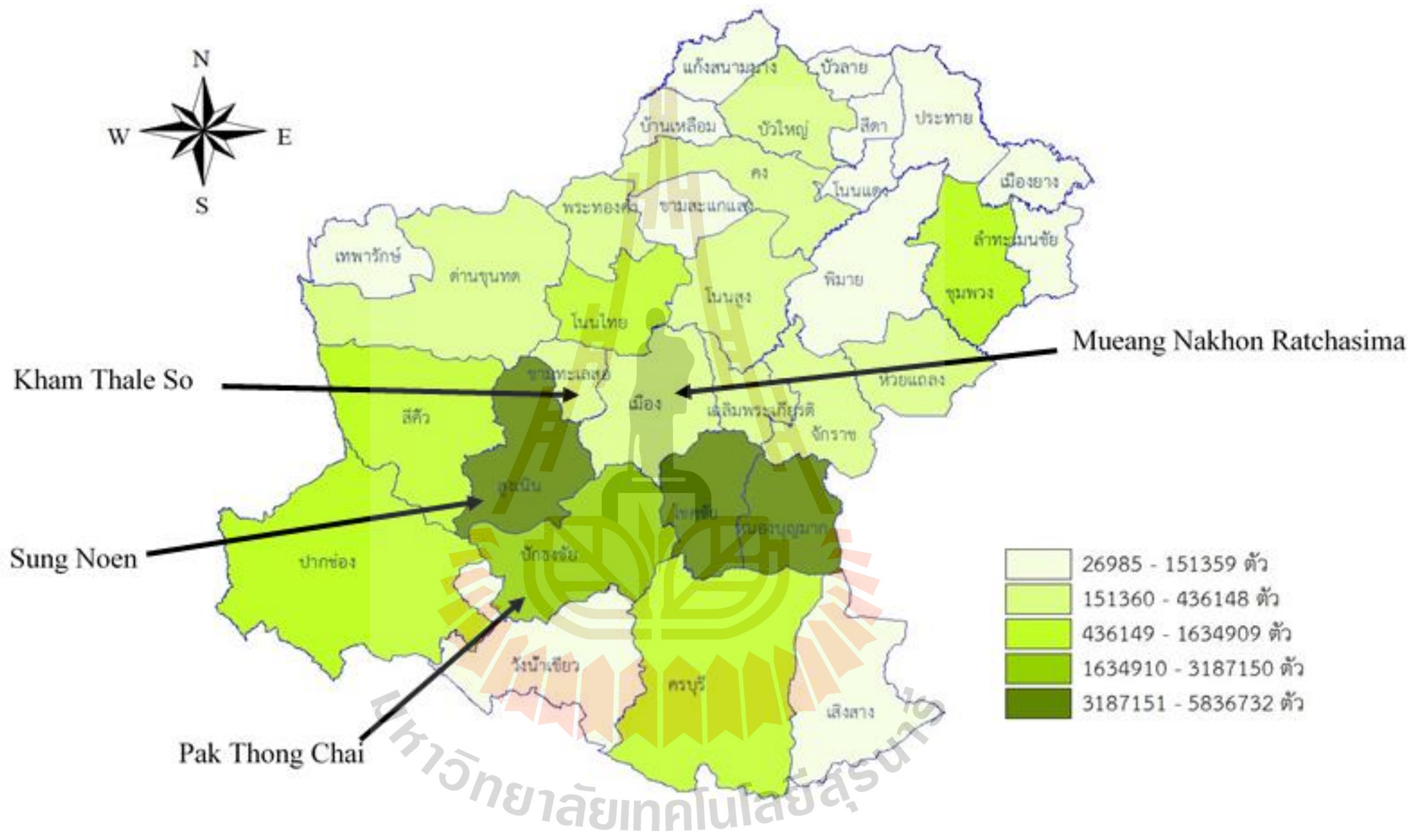

Figure 3.2 The study sites: Districts in Nakhon Ratchasima showing numbers of chicken production.

(http://pvlo-nak.dld.go.th/data/zone/zone57/chic57.jpg, 2015)

Table 3.1 The calculated number of samples of Nile tilapia farms.

Districts	The size of farm				Subsistence farming	Commercial farming
	<1 rais and feed	1 - 5 rais and feed	>5 rais and feed	Sum		
Mueang Nakhon Ratchasima	223	655	62	940	808	132
Pak Thong Chai	402	656	8	1,066	1,043	23
Total				2,006	1,851	155

Source: Fishery Office in Nakhon Ratchasima, (2015).

3.2 Work procedures

The study on carbon massflow, carbon fixation and carbon emission to develop carbon footprints from meat and egg productions of Thai native chicken and Nile tilapia farms was divided into 2 steps as follows:

Step 1: Field information

The purpose of this step was the primary data collection from Thai native chicken and fishery farms, factories and slaughterhouses from Mueang Nakhon Ratchasima, Kham Thale So, Sung Noen and Pak Thong Chai in Nakhon Ratchasima province. The information included types and amounts of animal feed, animal weight, ratio of animal parts in slaughterhouses and animal raising durations. Samples from the farms were collected by a random sampling method. Selected Thai native chicken were in meat and egg-laying stages. Sexes, ages, variety and status such as pregnant or unwell stages were not be considered.

Thai native chicken and Nile tilapia were existed on the farmer farms and all studied animals were in meat and egg-laying ages. This study was emphasized on types and amounts of animal feed which sources of animal feed were known and farms were well managed and registered. The evaluation and analysis of the systems were considered that those farms were at equilibrium stage by using carbon massflow concepts. Carbon massflow concepts were studied from common food plants or animal feed to these animals during feeding duration of each animal. This procedure investigated the net carbon transference from plants to animals (minus by carbon content in animal faeces) and then accumulated or fixed in animals in the farms of meat and egg for further consumption by humans. The four main energy uses were follows:

1) Electrical energy or fuel used in animal housing(kg.C/individual/day) such as heat energy that used in controlling temperature of housing, electricity, light and heat ventilation.

2) Energy use for slaughtering and for taking off animal hair and feather in slaughterhouse (kg.C/individual/day).

3) Maximum energy for freezing the meat (kg.C/individual/day).

4) Fuel energy for transportation of animals to slaughterhouses and transport -tation of meat to markets and meat-transform factories.

Step 2: Samples analysis in laboratory

The carbon content was studied by using CNS-2000 Elemental Analyzer and Gas Analyzer. Samples, including food plants and animal faeces were tested by heating at 550^{o}C for 30 minutes and using carbon analyzer.

The weight and type of food plants and animal feed used in the farms, weight of each animal, products from animals such as meat, eggs and faeces, CO_2 and CH_4 from animal digestion and respiration were investigated using the Convenience Sampling Methods (Cavana et al., 2000; Marks, 1982). Samples of meat, eggs, faeces and food plants or animal feed were analyzed to investigate the parameters in laboratory as summarized in Table 3.2.

The data of carbon content from the laboratory then was used as sources to study the average of carbon from animal activities (kg.C/individual/day) and to find carbon transfer rate from plants to animals. The carbon emission in terms of CO_2 and CH_4 were also investigated (UNECE, 2004).

Table 3.2 Analyzing methods to study food plant, meat, egg and faeces.

Parameter	Method	References
% Moisture	Know sampling dried weight, dried at 103 - 105°C for 24 hrs	Manlay et al. (2004a)
Carbon content (C)	CNS-2000 Elemental Analyzer and Gas Analyzer Respiration Trial System	Manlay et al. (2004b) Kawashima et al. (2000)
Volatile solid	Lost weight from known weight or volume of samples, Incinerate at 550°C for 30 min	APHA, AWWA, WEF. (1992)
Fixed solid	Remain weight from known weight or volume, incinerate at 550°C for 30 min	APHA, AWWA, WEF. (1992)
Weight	Weigh chicken and fish, using chicken and fish weighing tapes	Bunyavejchewin et al. (1985)

3.3 Data analyse

The data of all carbons which related with food productions such as carbon in food, meat, faeces and carbon in form of energy use from productions were analyzed. The results were explained the ratio of carbon emission to carbon fixation in form of food production and were explained the environmental impact from carbon emission. The analyses of some important processes were as follows:

3.3.1 The analysis for Thai native chicken

1) Carbon emission (C-emitted) was total carbon that secreted in the form of faeces (C-output) and gasses i.e. CO_2 and CH_4 from animal respiration and digestion (C-emission) per time. C-emitted for each animal is shown in the formula 6.

$$C - \text{emitted} = (C \text{ output} + C \text{ emissions}) \text{ per time} \tag{6}$$

2) Carbon fixation rate from food plants to Thai native chicken in plantweight and chicken weight compare to time is shown in the formula 7.

$$C - \text{fixation} = (C \text{ input} - C \text{ emitted}) \text{ per time} \tag{7}$$

3) The analysis for ranking the importance of each animal forthe production of meat and egg which show the least impact on environment by comparing the carbon emission and carbon fixation in human food and can be shown in formula 8 and formula 9.

$$\underset{\text{(Same level of C – fixation)}}{\text{Ratio of environment impact}} = \frac{\text{C emitted}}{\text{C fixation}} \tag{8}$$

$$\underset{\text{(Same amount of feed)}}{\text{Ratio of environment impact}} = \frac{\text{C emitted}}{\text{C input}} \tag{9}$$

Where:

Carbon fixation = carbon from meat and egg

Carbon emitted = carbon from respiration, digestion and faeces

Carbon input = carbon from artificial diet

3.3.2 The analysis for Nile tilapia

1) The carbon emission ($C_{emitted}$) is total carbons that secreted in form:

- Carbon from faeces (C_{output}) and gasses such as CO_2 and CH_4 from respiration and digestion ($C_{emission}$) per time are:

$$C_{emitted\ from\ Nile\ tilapia} = (C_{faeces} + C\ gasses\ from\ faeces + C\ from\ respiration\ and\ digestion\ of\ Nile\ tilapia)\ per\ time \quad (10)$$

- Carbon from total energy use in hatchery farms, aquaculture farms, catching, transportation and storage of fish and fish meat products are:

$$C_{emitted\ from\ energy\ use} = (C_{hatchery} + C_{farms} + C_{catching} + C_{transportation} + C_{storage})\ per\ time \quad (11)$$

2) The carbon fixation rate from aquatic food to Nile tilapia by food's weight and Nile tilapia's weight compared to time is shown as follow:

$$C_{fixation} = (C_{food} - C_{faeces} - C_{faeces\ gasses} - C\ from\ respiration\ and\ digestion\ of\ Nile\ tilapia)\ per\ time \quad (12)$$

3.4 Statistical analyses

Statistical analyses were performed using SPSS Version 18. The data subjected to analysis of variance (ANOVA) of the various parameters were used to compare the differences among tested animals and the differences between means were evaluated by Duncan's Multiple Range Test at 95% confidence level (Steel and Torrie, 1980).

CHAPTER IV

RESULTS AND DISCUSSIONS

The chapter IV results and discussions is separated into two parts, Part I is concerned about Thai native chicken and Part II is Nile tilapia. Results and discussions of these two parts are different methodology but the analyses are almost the same methods.

Part I Thai native chicken

4.1 Rate of carbon massflow in Thai native chicken production

4.1.1 Carbon input, carbon fixation and carbon emission in Thai native chicken

The carbon contents in the unit of kilogramme carbon per kilogramme Thai native chicken production per day (kg.C/kg.Thai native chicken/day) were used to investigate the comparison of carbon massflow from animal feed to biomass of Thai native chicken (C-input), carbon mass which was fixed in Thai native chicken bodies (C-fixation) and the carbon emitted in faeces, digestion and respiration (C-emission).

This results found that the rate of carbon transference from animal feed in Thai native chicken in Mueang Nakhon Ratchasima, Kham Thale So, Sung Noen and Pak Thong Chai districts of Nakhon Ratchasima province was 0.042 ± 0.39 kg.C/kg. Thai native chicken/day. Carbon fixation was calculated by the mass balance. The C-input minus the carbon emission in faeces, enteric fermentation, and respiration

(C-emission) was carbon mass fixed in the body (C-fixation). The carbon fixation of Thai native chicken was 0.033 ± 0.47 kg.C/kg.Thai native chicken/day. The carbon emission (C-emitted) from faeces, enteric fermentation, and respiration was 0.016 ± 0.59 kg.C/kg.Thai native chicken/day. The Thai native chicken showed carbon fixation efficiency at 64.79%. Thai native chicken emitted carbon from the same weight at 13.33×10^{-3} kg.C/kg.Thai native chicken/day. The rate of carbon input from animal feed to Thai native chicken by consumption including carbon fixation in this animal bodies and faeces during rearing duration are shown in Tables 4.1 to 4.3 and Table 4.11.

Nonetheless, total carbon emission per day from a Thai native chicken was 0.016 ± 0.59 kg.C/kg.Thai native chicken/day. Carbon fixation efficiency of Thai native chicken was at 64.79% of all carbon emission as shown in Tables 4.1 and 4.2. Carbon in form of carbon dioxide (CO_2) and methane (CH_4) from respiration and excretion of Thai native chicken was at 22.58% of carbon emission. One Thai native chicken had close figure of carbon emission at 0.016 ± 0.04 kg.C/kg.Thai native chicken/day. The carbon content in faeces of Thai native chicken was 74.16%. Whereas the carbon content in form of CO_2 and CH_4 from respiration and digestion of Thai native chicken was 3.26% of total carbon emission. The results are shown in Table 4.5 and Figure 4.1.

The average amounts of carbon which were released in the form of CO_2 and CH_4 from faeces, digestion and respiration of animal are shown in Tables 4.4 and 4.6 and Figure 4.2. For the proportion of CO_2 and CH_4 emission, Thai native chicken emitted at 5.333×10^{-3} time compared with the same weight of Thai native chicken. The global warming potentials (GWP) of CH_4 is estimated to be 21 times that of CO_2

and nitrous oxide (N_2O) almost 310 times that of CO_2 (IPCC, 2001). Therefore, this study can be concluded that a Thai native chicken had contribution to the cause of global warming.

Table 4.1 Rate of carbon input, carbon fixation and carbon emission of animal (mean ± S.D.).

Animal	Thai native chicken
C-input (kg.C/kg.Thai native chicken/day)	0.042 ± 0.39
C-input/same Thai native chicken (kg.C-input/kg Thai native chicken/day)	39.83×10^{-3}
C-fixation (kg.C/kg.Thai native chicken/day)	0.033 ± 0.47
C-fixation/same Thai native chicken (kg.C-input/kg Thai native chicken/day)	25.83×10^{-3}
C-emission (kg.C/kg.Thai native chicken/day)	0.016 ± 0.59
C-emitted/same weight Thai native chicken (emission/kg Thai native chicken/day)	13.33×10^{-3}
C-emission/C input (%)	33.48
C-emission/C fixation (%)	51.61
Fixation effiedcy C = (C-input - C-emission)/C-input (%)	64.79

Table 4.2 Rates of carbon input, carbon fixation and carbon emission of Thai native chicken.

Parameter	Thai native chicken
C-input (kg.C/kg.Thai native chicken/day)	39.83×10^{-3}
C-fixation (kg.C/kg.Thai native chicken/day)	25.83×10^{-3}
C-emission (kg.C/kg.Thai native chicken/day)	13.33×10^{-3}
C-emission/C-input (%)	33.48
C-emission/C-fixation (%)	51.61
Fixation efficiency C = (C-input - C-emission)/C-input (%)	64.79

Table 4.3 Carbon emission per individual per day of Thai native chicken.

Animal	Fresh faeces wt (kg./ kg.Thai native chicken /day)	% Faeces per Thai native chicken wieght	Carbon emission (kg.C/ kg.Thai native chicken /day)	Mean live animal weight in farm (kg.C/ kg.Thai native chicken)	Carbon emission from same weight (kg.C/ kg.Thai native chicken/day) $\times 10^{-3}$	Mean weight of egg (kg.C/ kg.Thai native chicken /day)
Thai native chicken	0.029	2.46	0.016 ± 0.59	1.18	39.32	N.A

Note: N.A = Not available.

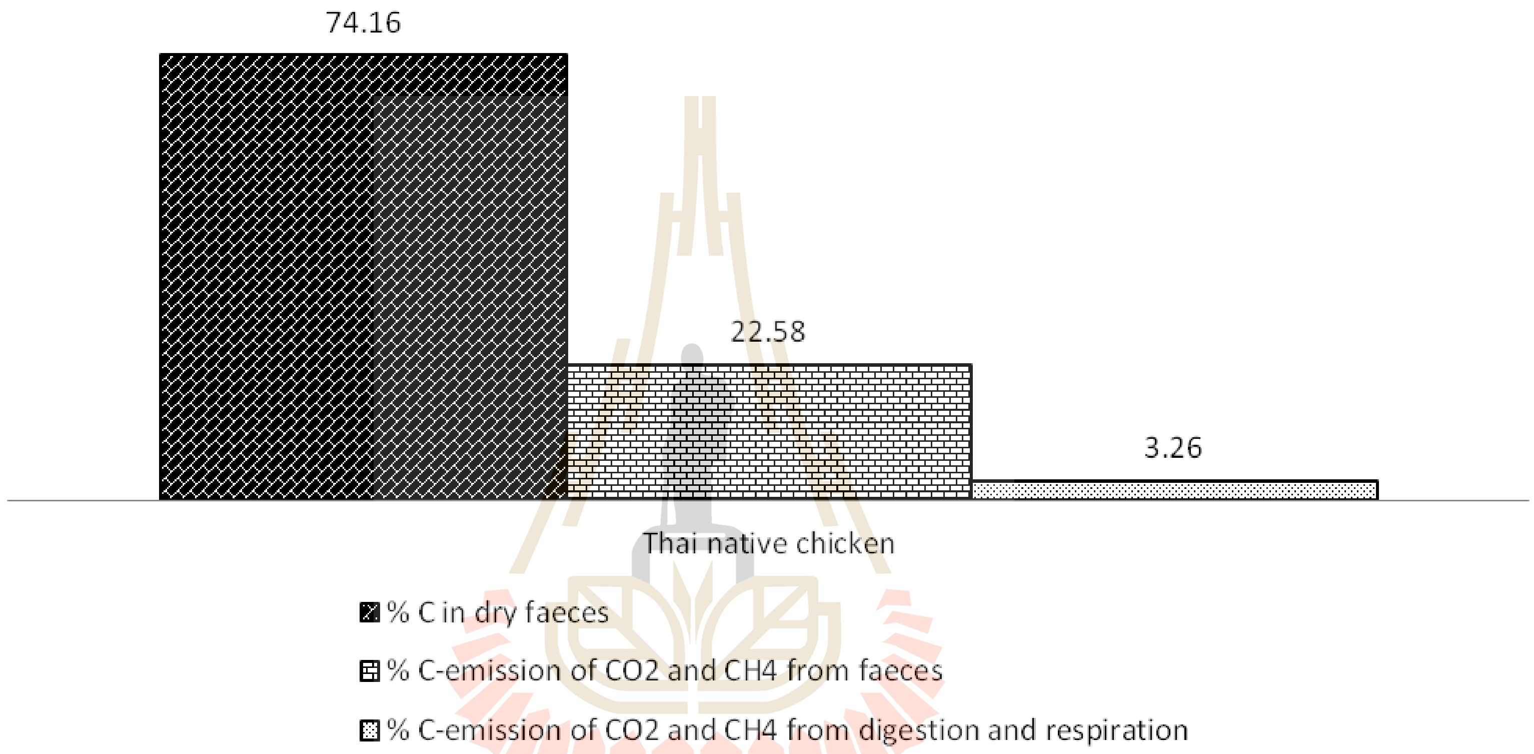

Figure 4.1 Ratio of carbon emission per individual per day from Thai native chicken.

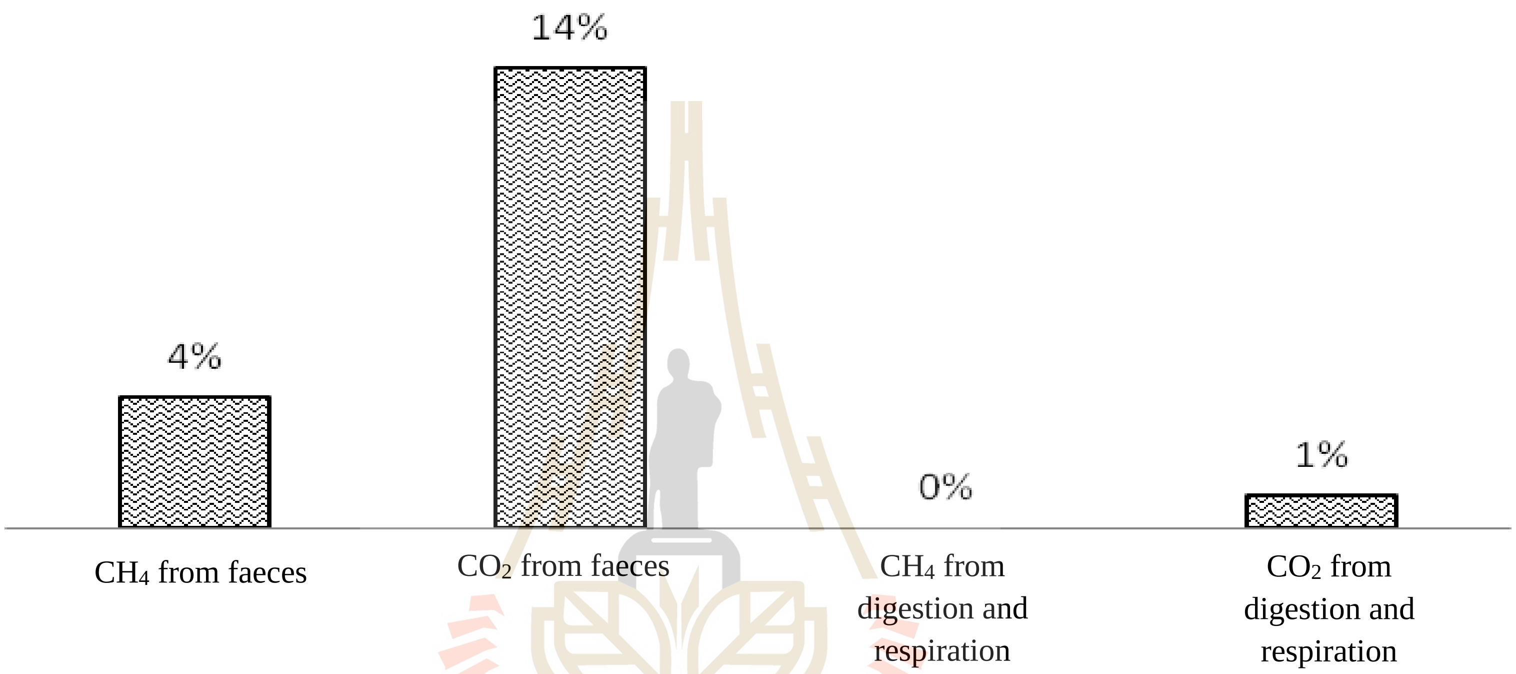

Figure 4.2 Percentages of CH_4 and CO_2 emission from faeces, digestion and respiration from same weight of Thai native chicken.

Table 4.4 Gases from Thai native chicken in Mueang Nakhon Ratchasima, Kham Thale So, Sung Noen and Pak Thong Chai districts of Nakhon Ratchasima province.

Animal	**Mean of gas from**	**CH_4 (kg.C/kg.Thai native chicken/day)**	**CO_2 (kg.C/kg.Thai native chicken/day)**	**Ratio CH_4 : CO_2**		**CH_4 : CO_2 At same weight**
Thai native chicken	Faeces	0.00001 ± 0.0000	0.0010 ± 0.0003	0.00001	Total 2 sources = 0.00090	7.605 × 10-4
	Digestion and respiration	N.D.	0.0068 ± 0.0005	0.0078		

The results of total carbon emission from each animal are shown in the Table 4.5. However, UNECE (2004) explained that the carbon emission by Mass Conservation Principle could tell total carbon emission from Thai native chicken per year correlated with the number of Thai native chicken as follows:

$$\text{C-emission}_{\text{Thai native chicken}} = (0.006)\ \text{Thai native chicken} \qquad (4.1)$$

Where:

$\text{C-emission}_{\text{Thai native chicken}}$ = total carbon emission from body of Thai native chicken (ton carbon per year.)

Thai native chicken = number of Thai native chickens (kg).

The rates of carbon transfer from animal feed to Thai native chicken by consumption (C-input) and then fixed in Thai native chicken bodies, organs (C-fixation), as well as, the carbon contents from Thai native chicken faeces excreted and carbon in forms of CO_2 and CH_4 from digestion and respiration of Thai native chicken (C-emission) during rearing duration are shown in Table 4.5. Thai native chicken could consume low nutrient intake. The nutrient in digestive system fermented by aerobic bacteria methane (CH_4). It has been cleared the global warming potentials (GWP) of CH_4 are estimated to be 21 times that of CO_2. The relationship between carbon consumption (C-input) and carbon emission from livestock animals (C-emission) at a confidence level of 95% is illustrated in Figure 4.3.

Table 4.5 Average of carbon input (C-plant) fixed in Thai native chicken (C-fixation) emitted from Thai native chicken (C-emission) in faeces (C-output) and C-emission of CO_2 and CH_4 from respiration and digestion (mean ± S.D.).

animal	Amount C-transferred from feed to chicken (kg.C/kg. chicken/day)	Carbon fixatiom (kg.C/animal/day)					Carbon emitted (kg.C/animal/day)			
		Egg	Total C-accumulatated in body (mass Equilibrium)	meat	intrails	Bone, skin, blood etc (mass equilibrium)	Total C-emitted from chicken	Dry faeces	C-emission of CO_2 and CH_4	
									faeces	Digestion and respiration
Thai native chicken	0.047 ± 0.48	N.D.	0.031 ± 0.49	0.005 ± 0.89	0.0008 ± 1.14	0.025	0.016 ± 0.04	0.006 ± 0.196	0.0003 ± 0.09	0.0097 ± 0.04

Note: N.D. = not defection.

The results of regression analysis can be summarized the relationship between C-emission and C-input of Thai native chicken as shown in the equations 4.2.

$$C\text{-emission}_{\text{Thai native chicken}} = 0.353\,(C\text{-input}_{\text{Thai native chicken feed}}) + 0.061$$

$$R^2 = 0.96 \qquad (4.2)$$

Where:

$C\text{-emission}_{\text{Thai native chicken}}$ = carbon emitted from Thai native chicken (kg.C/kg.Thai native chicken/day)

$C\text{-input}_{\text{Thai native chicken feed}}$ = carbon content in feed which transferred to Thai native chicken by consumption at Thai native chicken meat duration or average age at 56.63 ± 1.72 days with average value at 0.047 ± 0.048 (kg.C/ kg.Thai native chicken/day)

The comparison of the percentage of average carbons which was fixed in studied animals per average carbon content in animal feed per day ($C\text{-}_{\text{fixation}}/C\text{-}_{\text{input}}$) found that Thai native chicken fixed 64.85% carbon from animal feed (Table 4.6).

Table 4.6 Average percentage of carbon fixation in Thai native chicken parts (mean ± S.D.).

Animal	**Total meat (%)**	**Total entrail (%)**	**Skin, blood, bone, head, ect. (%)**	**C-fixation /C-input (%)**
Thai native chicken	49.11 ± 0.89	11.37 ± 1.14	39.52 ± 1.75	64.85

The results of the fixation rates from animal feed to Thai native chicken by consumption in raising durations and the Principle of Mass Conservation (UNECE, 2004) can be shown the carbon input and carbon fixation in Thai native chicken as follows:

$$C_{\text{-input}} = (0.017)\ \text{Thai native chicken} \quad (4.3)$$

$$C_{\text{-fixation}} = (0.011)\ \text{Thai native chicken} \quad (4.4)$$

Where:

$C_{\text{-input}}$ = carbon mass emission from animal feed to Thai native chicken by consumption Thai native chicken in utilized age (ton carbon per year).

$C_{\text{-fixation}}$ = carbon fixation in Thai native chicken body included eggs (toncarbon per year).

Thai native chicken = number of Thai native chicken (kg).

Concurrently, the consideration of relation between carbon input to Thai native chicken by feed consumption and carbon fixation in each Thai native chicken which ia shown in the formulas 4.5 by analysis of the relationships of each Thai native chicken at 95% confidence ($p \leq 0.05$) as shown in formula 4.5.

$$C\text{-fixation}_{\text{Thai native chicken}} = 0.760\,(C\text{-input}_{\text{Thai native chicken}}) + 0.049$$

$$R^2 = 0.91 \qquad (4.5)$$

Where:

$C\text{-fixation}_{\text{Thai native chicken}}$ = carbon fixation from Thai native chicken (kg.C/kg.Thai native chicken/day)

$C\text{-input}_{\text{Thai native chicken feed}}$ = carbon content in feed which transferred to Thai native chicken by consumption at meat duration or average age of 56.63 ± 1.72 days with average value at 0.047 ± 0.048 (kg.C/kg.Thai native chicken/day)

Moreover, the proportion of carbon content of animal feed which was transferred to Thai native chicken and fixed into parts of Thai native chicken bodies and faeces including carbon in the form of CO_2, CH_4 from digestion and respiration per Thai native chicken per day was also analyzed. Carbon contents of 100 parts in animal feed, were fixed in bodies of Thai native chicken at 51%. The rest of carbon contents were released from Thai native chicken through the excretion of waste, respiration and digestion at 23%. These carbons were important parts in causing the environmental problems. The result showed that Thai native chicken fixed most carbon in their bodies and released lowest carbon. Moreover, the Thai native chicken had percent carbon which was entrail at 3%. The results are illustrated in Figures 4.3.

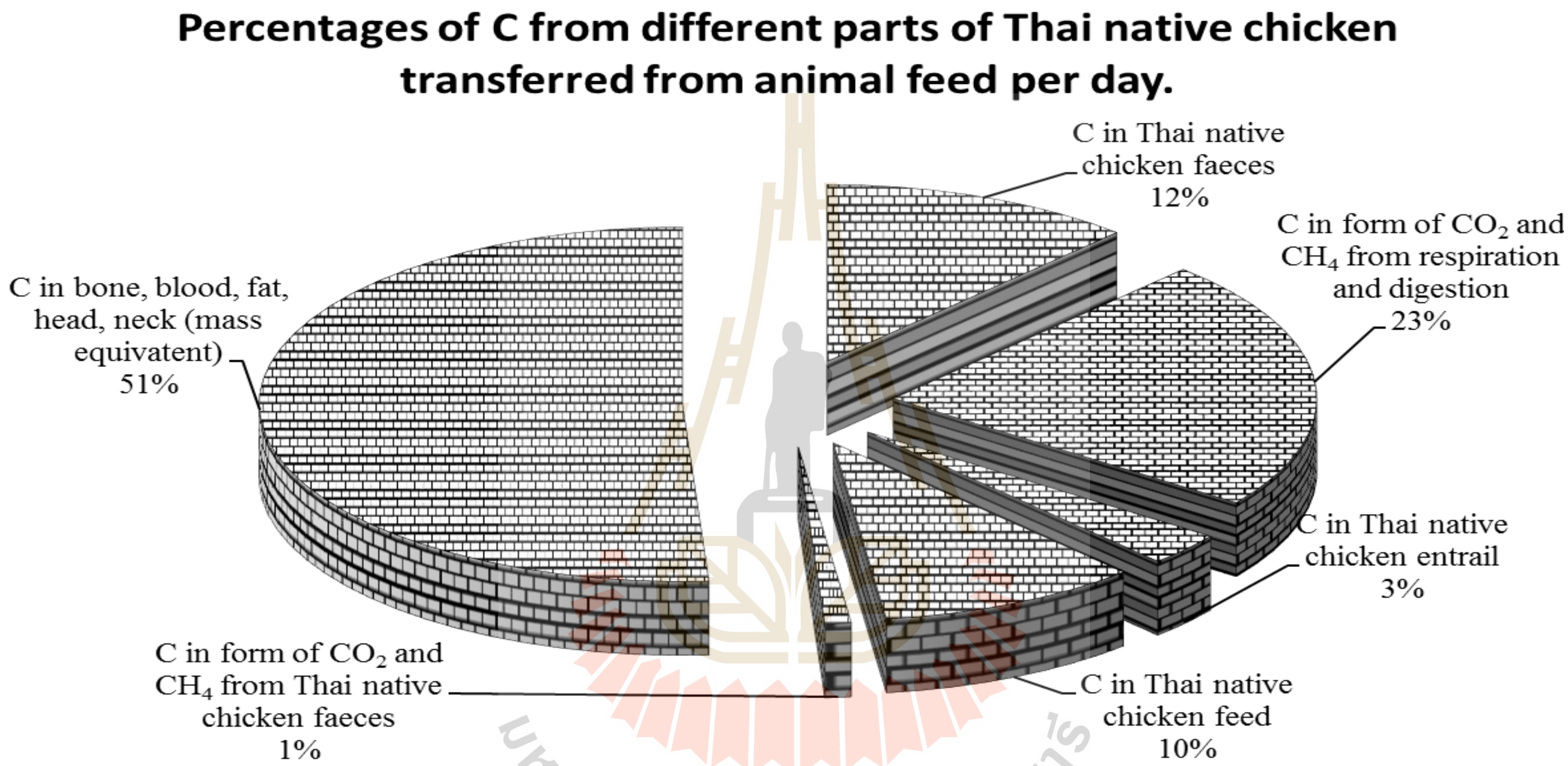

Figure 4.3 Percentages of carbon from different parts of Thai native chicken transferred from animal feed per day.

4.1.2 Carbon fixation and carbon emission in Thai native chicken production in selected districts of Nakhon Ratchasima province

The carbon contents in unit of kg carbon per kg animal production per day (kg.C/kg.Thai native chicken/day) were used to study carbon massflow from animal feed to biomass of Thai native chicken (C-input), and the carbon mass which was fixed in the Thai native chicken bodies (C-fixation). Carbon emitted in the forms of CO_2 and CH_4 from faeces, digestion and respiration (C-emission) in Mueang Nakhon Ratchasima district, Kham Thale So district, Sung Noen district and Pak Thong Chai district at Nakhon Ratchasima province, Thailand were also evaluated.

The results of this evaluation found that carbon massflow from animal feed of Thai native chicken (C-input) in Sung Noen district had the highest value at 43.592×10^{-3} kg.C/kg.Thai native chicken/day, followed by in Kham Thale So district at 42.981×10^{-3} kg.C/kg.Thai native chicken/day and Pak Thong Chai district at 39.538×10^{-3} kg.C/kg.Thai native chicken/day, whereas the lowest in Mueang Nakhon Ratchasima district at 33.330×10^{-3} kg.C/kg.C/kg.Thai native chicken/day. In addition, the rate of carbon input from animal feed consumption, including carbon fixation in Thai native chicken bodies (C-fixation) in Sung Noen district had the highest value at 28.947×10^{-3} followed by in Kham Thale So district at 26.205×10^{-3}, Pak Thong Chai district at 23.861×10^{-3} and Mueang Nakhon Ratchasima district at 21.951×10^{-3} kg.C/kg.Thai native chicken/day, respectively.

Moreover, the carbon emission from enteric fermentation, faeces and respiration (C-emission) in Sung Noen district showed the highest carbon emission among selecked areas at 15.385×10^{-3} kg.C/kg.Thai native chicken/day. While Kham Thale So district had the second highest carbon emission at 14.305×10^{-3}

kg.C/kg.Thai native chicken/day, followed by Pak Thong Chai district at 13.289×10^{-3} kg.C/kg.Thai native chicken/day and Mueang Nakhon Ratchasima district had the lowest carbon emission at 11.328×10^{-3} kg.C/kg.Thai native chicken/day. This probably because of the different distances and farm management and the system of farms which could be close system or open system. This result coincide with the report of Keeratiurai et al. (2013).

Furthermore, the carbon emission from energy used in farms and slaughterhouses were also taken into account. The study found that in Mueang Nakhon Ratchasima district presented the highest carbon emission at 63.248×10^{-3} kg.C/kg.Thai native chicken/day. In Pak Thong Chai district had carbon emission at 61.404×10^{-3} kg.C/kg.Thai native chicken/day, Kham Thale So district had carbon emission at 59.296×10^{-3} kg.C/kg.Thai native chicken/day and Sung Noen district showed the lowest carbon emission value at 57.723×10^{-3} kg.C/kg.Thai native chicken/day. This due to the distance from animal feed factories to farms, parent stock farms to farms, farms to slaughterhouses and slaughterhouses to markets. The results are shown in Tables 4.7 to 4.8 and Figure 4.4.

According to the carbon emission from Thai native chicken production the results showed that the comparison of carbon fixation efficiency $[(C_{input} - C_{emission})/C_{input}]$ of Thai native chicken production was higher in Mueang Nakhon Ratchasima district than Pak Thong Chai district, Kham Thale So district and Sung Noen district which were 67.53%, 66.72%, 65.85% and 64.71%, respectively.

Table 4.7 Rates of carbon input, carbon fixation and carbon emission of Thai native chicken at the same weight in Mueang Nakhon Ratchasima, Kham Thale So, Sung Noen and Pak Thong Chai districts (mean ± S.D.).

District	**Mueang Nakhon Ratchasima**	**Kham Thale So**	**Sung Noen**	**Pak Thong Chai**
Mean live animal weight in farm (kg./ind)	1.14	1.27	1.21	1.13
C_{-input} (kg.C/kg.animal/day)	0.049 ± 0.51	0.051 ± 0.53	0.053 ± 0.63	0.041 ± 0.39
C_{-input}/same animal (kg.C_{-input}/kg animal/day)	33.33×10^{-3}	42.981×10^{-3}	43.592×10^{-3}	39.538×10^{-3}
C-fixation (kg.C/kg. animal/day)	0.033 ± 0.51	0.027 ± 0.48	0.033 ± 0.47	0.027 ± 0.63
$C_{fixation}$/same animal (kg. C_{-input} /kg animal/day)	21.951×10^{-3}	26.205×10^{-3}	28.947×10^{-3}	23.861×10^{-3}
$C_{emission}$ (kg.C/kg.animal/day)	0.016 ± 0.65	0.014 ± 0.61	0.018 ± 0.49	0.015 ± 0.08
Cemitted/same animal Cemission/kg animal/day)	11.328×10^{-3}	14.305×10^{-3}	15.385×10^{-3}	13.289×10^{-3}
C-emission/Cinput (%)	32.65	34.15	35.29	31.46
C-emission/Cfixation (%)	48.48	51.85	54.55	47.36
Fixation effiedcy C = (C-input - C-emission)/C-input (%)	67.53	65.85	64.71	66.72

Table 4.8 Average of C-emission from energy in farm and slaughterhouse of Thai native chicken in Mueang Nakhon Ratchasima, Kham Thale So, Sung Noen and Pak Thong Chai districts (mean ± S.D.).

Average C from energy		C-emission (kg.C/livestock animal/day)			
		Mueang Nakhon Ratchasima	**Kham Thale So**	**Sung Noen**	**Pak Thong Chai**
Farm	Electricity	0.001 ± 0.02	0.001 ± 0.02	0.001 ± 0.02	0.001 ± 0.02
	Fuel for transpotation	0.027 ± 0.011	0.026 ± 0.009	0.024 ± 0.007	0.028 ± 0.106
	Fuel for machine or LPG	N.D.	N.D.	N.D.	N.D.
	Total C from energy/kg.animal/day	0.028	0.027	0.025	0.029
	Total for energy/animal/day	23.932×10^{-3}	22.619×10^{-3}	21.951×10^{-3}	25.439×10^{-3}
Slaughterhouse	Electricity	0.004 ± 0.013	0.003 ± 0.002	0.003 ± 0.013	0.004 ± 0.032
	Fuel for transpotation	0.020 ± 0.117	0.017 ± 0.002	0.018±0.009	0.016 ± 0.003
	Wood chaff LPG	0.022 ± 0.007	0.023 ± 0.015	0.025 ± 1.02	0.021 ± 0.038
	Total C from energy/kg.animal/day	0.046	0.042	0.044	0.041
	Total for energy/animal/day	39.016×10^{-3}	35.772×10^{-3}	34.429×10^{-3}	35.965×10^{-3}
Total Cemission from energy of two source	**kg.C/kg.animal/day**	**0.102**	**0.071**	**0.069**	**0.070**
	kg.C/animal/day	$\mathbf{63.248 \times 10^{-3}}$	$\mathbf{59.296 \times 10^{-3}}$	$\mathbf{57.723 \times 10^{-3}}$	$\mathbf{61.404 \times 10^{-3}}$

Note: Report and charts of CNPP THAILAND 2013 and TGO Common data (2011) have analyzed CO2 emission from electricity = 0.5610 kg.CO_2/kWh or 0.153 kg.C/kWh; Intergovernmental Panel on Climate Change (2007) has identified the CO_2 emission from fuel energy used (diesel) for transportation = 0.094 kg.CO_2/1 ton-km or 0.014 kg.C/1 ton-km; CO_2 emission from diesel (stationary combustion) = 2.7080 kg.CO_2/L; CO_2 emission from LPG used = 3.11 kg.CO_2/1 kg.LPG 0r 0.848 kg.C/1 kg.LPG. N.D. = not defection.

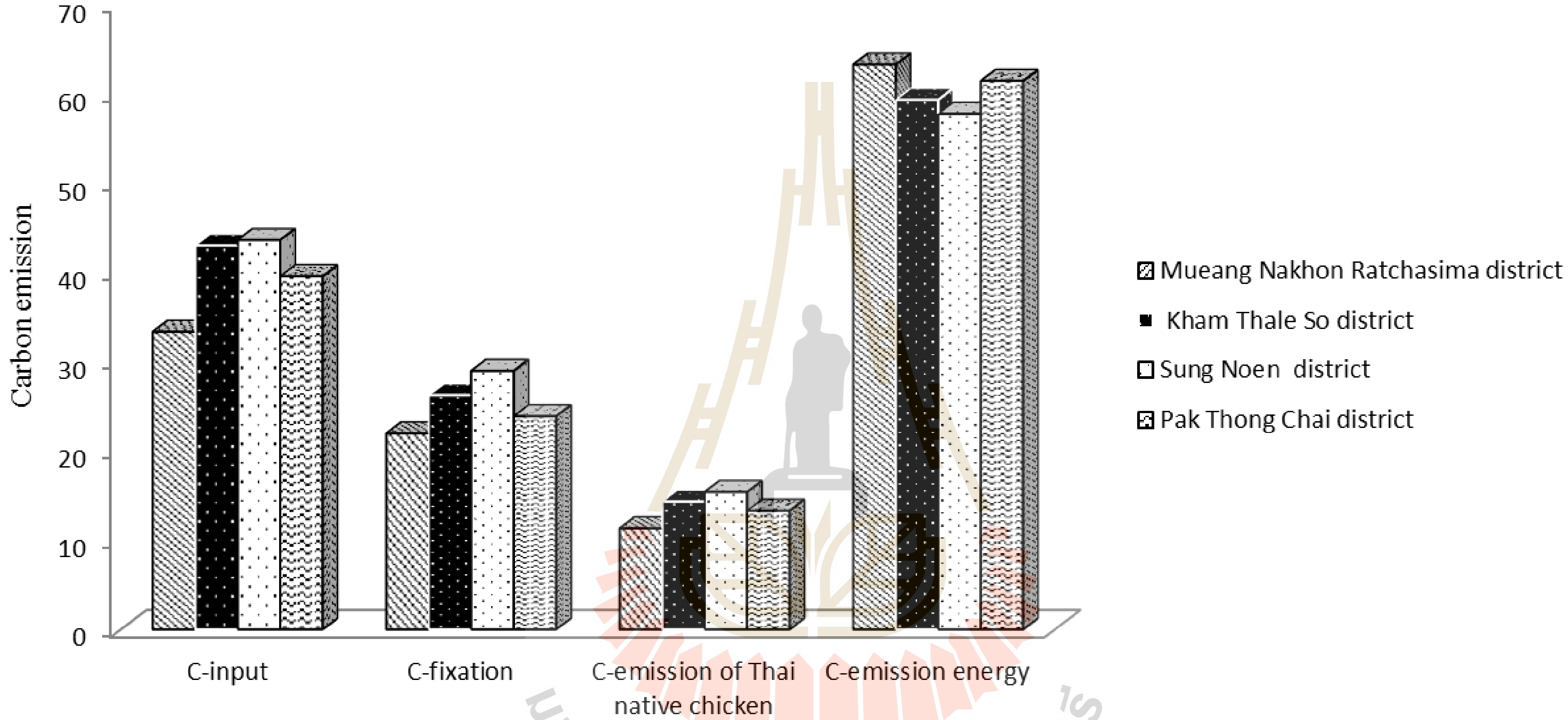

Figure 4.4 Carbon emission of Thai native chicken production in Mueang Nakhon Ratchasima, Kham Thale So, Sung Noen and Pak Thong Chai districts (kg.C/kg.Thai native chicken/day).

4.2 Carbon emission from energy use in meat and egg productions

The survey of farms and slaughterhouses in studied districts found that Thai native chicken farms had used much energy for raising chicken per kilogramme chicken per day (kg.C/kg.Thai native chicken/day). Most of energy used was energy for water pumps, transportation of chicken, eggs, feed and chicken to slaughterhouses, and LPG or electricity for small chick incubation. The Thai native chicken farms used energy for transportation of feed, chicks, mature laying bird to farms and slaughterhouses and egg transportation to markets. The result revealed that the total carbon emission from energy at weight of chicken production was 59.332×10^{-3} kg.C/kg.Thai native chicken/day which results are shown in Table 4.9.

Additionally, the slaughterhouses used most of energy for water pumps, light and transportation of Thai native chicken meat production. Besides these, slaughterhouses used wood, chaff or LPG for boiling water in cleaning process, taking of hair and leather of Thai native chicken. The results found that total carbon emission of these two sources from Thai native chicken was 35.593×10^{-3} kg.C/kg.Thai native chicken/day.

Consequently, it was found that most of carbon emissions from egg productions in farms were used for transportation (Figure 4.5, Table 4.9). The total carbon emission from the use of energy from farms and slaughterhouses found that Thai native chicken production from energy used at 0.07 kg.C/Thai native chicken/day (Table 4.9). The use of energy from fuel, LPG, chaff and wood in chicken meat productions are shown in Figure 4.5. This result coincide with the finding of Thenee et al. (2008), Thenee et al. (2009a), Vichairattanatrakul (2014).

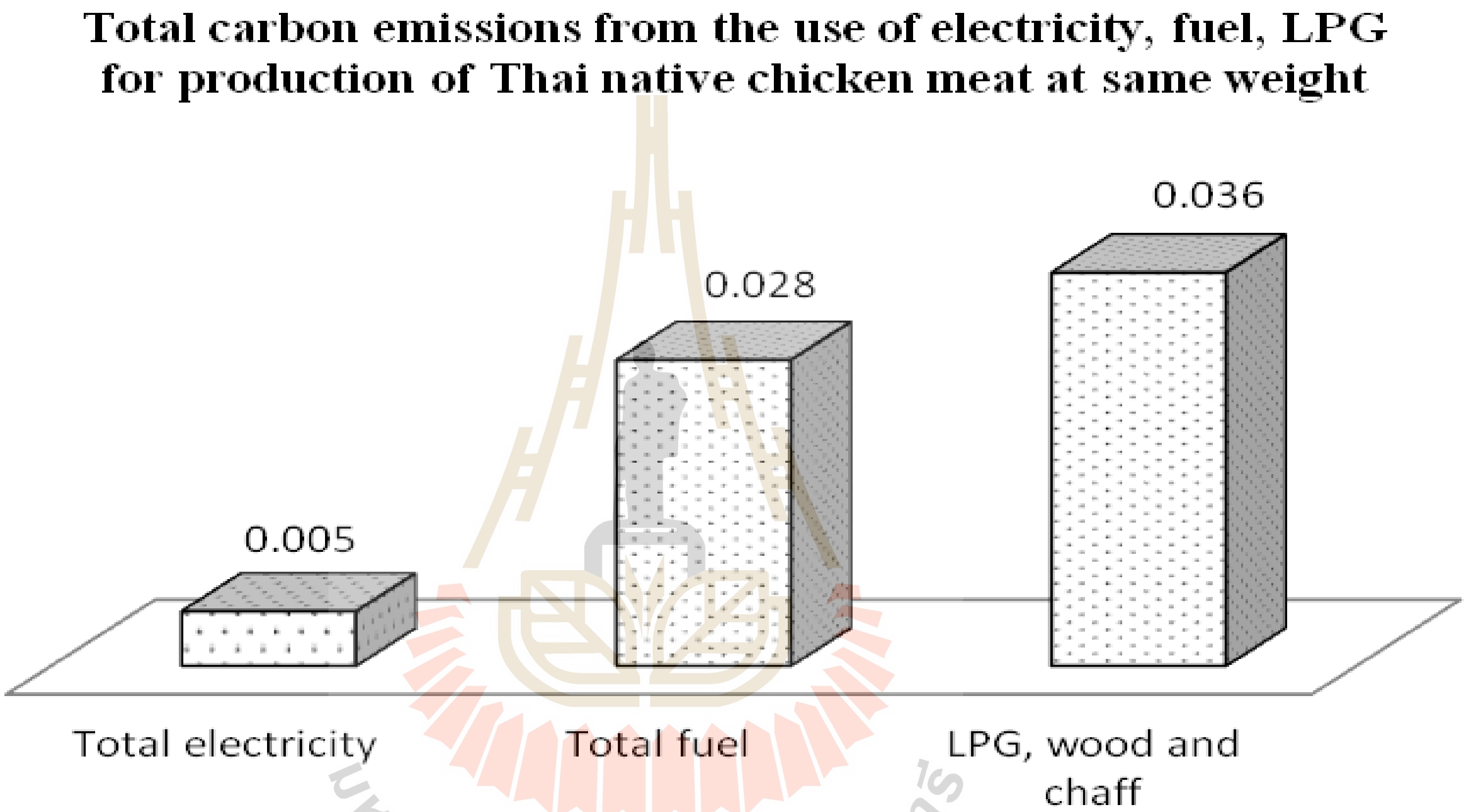

Figure 4.5 Total carbon emissions from the use of electricity, fuel, LPG for production of Thai native chicken meat at same weight (kg.C/Thai native chicken/day).

Table 4.9 Average of C-emission from energy in farm and slaughterhouse (mean ± S.D.).

Average C from energy		C-emission (kg.C/animal/day)
		Thai native chicken
Farm	Electricity	0.001 ± 0.02
	Fuel for transpotation	0.027 ± 0.149
	Fuel for machine or LPG	N.D.
	Total C from energy/kg.Thai native chicken/day	0.028
	Total for energy/Thai native chicken/day	23.729×10^{-3}
Slaughterhouse	Electricity	0.004 ± 0.032
	Fuel for transpotation	0.002 ± 0.009
	Wood chaff LPG	0.036 ± 0.038
	Total C from energy/kg.Thai native chicken/day	0.042
	Total for energy/Thai native chicken/day	35.593×10^{-3}
Total Cemission from energy of two source	**kg.C/kg.Thai native chicken/day**	**0.070**
	kg.C/Thai native chicken/day	**59.322×10^{-3}**

Note: Report and charts of CNPP THAILAND 2013 and TGO Common data (2011) have analyzed CO_2 emission from electricity = 0.5610 kg.CO_2/kWh or 0.153 kg.C/kWh; Intergovernmental Panel on Climate Change (2007) has identified the CO_2 emission from fuel energy used (diesel) for transportation = 0.094 kg.CO_2/1 ton-km or 0.014 kg.C/1 ton-km; CO_2 emission from diesel (stationary combustion) = 2.7080 kg.CO_2/L; CO_2 emission from LPG used = 3.11 kg.CO_2/I kg.LPG or 0.848 kg.C/1 kg.LPG. N.D. = not defection.

Nonetheless, at the same weight for each Thai native chicken (1 kg of live weight) it was found that Thai native chicken emitted carbon from the use of energy for meat productions at 24.10%. However, the total carbon emission from Thai native chicken production was the highest at 71.652 × 10^{-3} kg.C/kg.Thai native chicken/day as shown in Table 4.12. It can be concluded that Thai native chicken productions from livestock farms create environmental impact, especially carbon emission from the use of energy. This result supports the of Keeratiurai et al. (2013) which stated that lager farming in Nakhon Ratchasima emitted hight GHG during the production. Thenprocedure is shown in formula 4.6.

$$C\text{-}emission_{energy} = (0.026)\ \text{Thai native chicken} \qquad (4.6)$$

Where:

$C\text{-}emission_{energy}$ = total carbon emission from body of Thai native chicken (ton carbon per year).

Thai native chicken = number of Thai native chicken (kg).

4.3 Relationship between carbon content in Thai native chicken feed, meat, egg and faeces, and chicken production

The results of the average dry weight of animal feed, meat, eggs and dry faeces which were explored by the amount of animal feed consumption and faeces excreted in one individual per day (including average living livestock animal weight from all livestock farms) could get the ratio of relationship between dry faeces weight per average dry weight of animal feed per day Thai native chicken released faeces at 22.45% of animal feed as shown in Table 4.10. Thai native chicken consumed only

2.14% of feed and released only 0.31% of faeces which was positively correlated with relationship between C-input and C-emission $_{\text{Thai native chicken}}$.

Table 4.10 Average and relationship between carbon, dry weight of animal feed and faeces from animal per day and average rearing duration of Thai native chicken (mean ± S.D.).

Animal	**Average rearing duration (day)**	**Dry faeces (kg/kg. animal/day)**	**Dry feed for animal consumption (kg/kg. animal/day)**	**Dry wt CH_4 form animal per kg. dry feed**	**Dry wt food consumption per kg. of live animal**	**Dry wt faeces per kg. live weight of animal**	**Dry kg.faeces per kg. of dry feed**	**C in form of CO_2 + CH_4 $_{per}$ feed**	**C faeces per C feed**
Thai native chicken	56.76 ± 4.17	0.024	0.047 ± 0.48	0.00%	3.98%	2.03%	51.01%	4.35%	35.66%

Table 4.11 Relationship between moisture, volatile solid and carbon content of feed, faeces, meat, entrail, and egg of Thai native chicken (TNC).

Animal	**Moisture (%)**	**Total volatile solid (%TVS)**	**Ash (%)**	**Carbon content (%C)**	**Relationship between %TVS and %C**	R^2
TNC feed	7.62 ± 1.25	71.82 ± 2.07	28.18 ± 2.07	44.06 ± 4.52 %	TVS = 0.40(%C) + 54.01	0.78
TNC meat	65.71 ± 6.57	81.98 ± 4.01	18.02 ± 4.01	46.40 ± 6.21 %	TVS = 0.59(%C) + 55.97	0.83
TNC tendon	51.08 ± 8.22	98.97 ± 1.26	11.03 ± 1.26	44.88 ± 0.79 %	TVS = 1.49(%C) + 18.26	0.87
TNC liver	73.92 ± 0.86	87.63 ± 1.31	12.37 ± 1.31	46.71 ± 1.18 %	TVS = 1.05(%C) + 36.61	0.80
TNC heat	71.66 ± 0.36	85.73 ± 1.96	14.27 ± 1.96	47.78 ± 2.28 %	TVS = 2.38(%C) - 82.67	0.79
TNC gizzard	76.94 ± 0.28	83.04 ± 1.09	16.96 ± 1.09	45.14 ± 0.79 %	TVS = 1.61(%C) + 26.33	0.70
TNC skin	75.49 ± 2.12	82.56 ± 0.66	17.44 ± 0.66	46.94 ± 1.94 %	TVS = 0.45(%C) + 69.42	0.88
TNC wing	62.45 ± 1.81	75.11 ± 0.81	24.89 ± 0.81	44.18 ± 1.04 %	TVS = 0.69(%C) + 49.63	0.89
TNC feed	66.63 ± 1.86	77.47 ± 0.61	22.54 ± 0.61	44.61 ± 1.23 %	TVS = 0.38(%C) + 42.39	0.82
TNC leg	61.07 ± 0.82	75.97 ± 1.76	24.03 ± 1.76	46.19 ±1.01 %	TVS = 1.16(%C) + 26.43	0.64
TNC faeces	71.51 ± 22.31	74.32 ± 9.16	25.68 ± 3.16	37.77 ± 2.43 %	TVS = 0.92(%C) + 33.23	0.72
TNC entrail	70.17 ± 3.01	78.87 ± 3.26	21.13 ± 3.26	49.31 ± 1.97 %	TVS = 1.33(%C) + 27.58	0.73

Part II Nile tilapia

4.4 Rate of carbon massflow in fishery farming system

4.4.1 Carbon input, carbon fixation, and carbon emission from Nile tilapia in selected districts of Nakhon Ratchasima province

The carbon contents in the unit of kg carbon per kg of fish product per day (kg.C/kg.fish/day) were used to study of carbon massflow from fishery food for feeding to the biomass of different fishery animals (C-input), the carbon mass that was fixed in the fishery body (C-fixation) and the carbon emitted in faeces, digestion and respiration (C-emission).

The results showed that Nile tilapia emitted carbon per day at 2.00×10^{-4} kg.C/kg.fish/day, but obtained the carbon at 7.70×10^{-3} kg.C/kg.fish/day. Nile tilapia fixed carbon in the body at 7.50×10^{-3} kg.C/kg.fish/day, which Nile tilapia in Pak Thong Chai district emitted higher carbon than in Mueang Nakhon Ratchasima district.

Furthermore, the rate of carbon transferred from animal feed to Nile tilapia was 1.20×10^{-3} and carbon emitted of fish was 5.90×10^{-4} kg.C/kg.fish/day. The efficiency of carbon fixation in fishery animal found that Nile tilapia efficiently fixed carbon in the body at 97.05%. The rate of total carbon input from fishery feed to Nile tilapia by consumption including carbon fixation in fishery animal bodies and faeces during rearing duration are shown in Table 4.12 and Table 4.13.

Additionally, Table 4.14 and Table 4.15 show the average of C-input from fishery feed, C-fixation in fishery animal bodies, C-output and C-emission in form of CO_2 and CH_4 from animal faeces, digestion and respiration. Nile tilapia emitted average total carbon per kg. The results showed that carbon emission of Nile tilapia was 2.00×10^{-4} kg.C/kg.Nile tilapia/day.

In addition, the results of carbon emissions of Nile tilapia in Mueang Nakhon Ratchasima district and Pak Thong Chai district of Nakhon Ratchasima provinces had a similar figure at 0.0002 ± 0.0000 kg.C/kg.fish/day. Carbon contents of Nile tilapia in Mueang Nakhon Ratchasima districe and Pak Thong Chai district at Nakhon Ratchasima provinces were 1.17% and 3.32% of total carbon emission, respectively (Table 4.16). Most of them were in form of fish faeces.

The quantity of carbon that was released in the form of carbon dioxide (CO_2) and methane (CH_4) from respiration and digestion of Nile tilapia is shown in the Figures 4.6. These values compared favorably with the reports to carbon emissions associated with beef, pork, poultry and sheep productions (Nemry, Theunis, Brechet, and Lopez, 2001; Thanee, Dankittikul, and Keeratiurai, 2009a, 2009b).

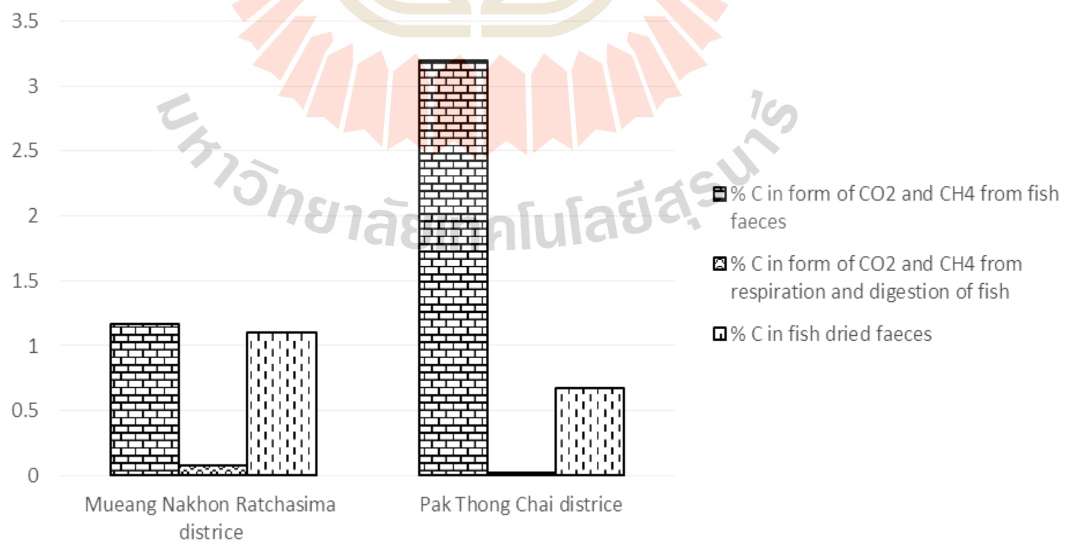

Figure 4.6 Proportion of carbon emission per 1 kg per day from different sources of Nile tilapia.

Table 4.12 Rates of carbon input, carbon fixation, and carbon emitted of Nile tilapia in Mueang Nakhon Ratchasima district (mean ± S.D.).

Carbon contents	Mueang Nakhon Ratchasima districe		
	<1 rais	**1 - 5 rais**	**<5 rais**
Average of live-weight fish[1]	2.4120 ± 1.2020	2.2817 ± 1.4152	2.3700 ± 0.1059
Weight of fresh faeces excreted[2]	0.0058 ± 0.0048	0.0054 ± 0.0048	0.0022 ± 0.0004
Percentage of faeces excreted per fish weight	9.62	11.83	4.64
C_{input}[3]	0.0060 ± 0.0075	0.0074 ± 0.0049	0.0047 ± 0.0004
$C_{fixation}$[3]	0.0058 ± 0.0074	0.0072 ± 0.0048	0.0044 ± 0.0003
$C_{emitted}$[3]	0.0002 ± 0.0001	0.0002 ± 0.0001	0.0003 ± 0.0001
$C_{emitted}/C_{input}$ (%)	3.33	2.70	6.38
$C_{emitted}/C_{fixation}$ (%)	3.45	2.78	6.82
Fixation efficiency, $C = (C_{input} - C_{emitted})/C_{input}$ (%)	96.67	97.30	93.62

Note: [1] Unit = kg per individual, [2] Unit = kg per kg of fish per day, [3] Unit = kg carbon per kg of fish per day.

Table 4.13 Rates of carbon input, carbon fixation, and carbon emitted of Nile tilapia in Pak Thong Chai district (mean ± S.D.).

Carbon contents	**Pak Thong Chai districe**		
	<1 rais	**1 - 5 rais**	**>5 rais**
Average of live-weight fish[1]	1.9533 ± 0.5222	1.3250 ± 0.1422	1.9500 ± 0.5272
Weight of fresh faeces excreted[2]	0.0073 ± 0.0029	0.0078 ± 0.0025	0.0066 ± 0.0039
Percentage of faeces excreted per fish weight	37.37	39.24	16.92
C_{input}[3]	0.0092 ± 0.0065	0.0079 ± 0.0029	0.0085 ± 0.0126
$C_{fixation}$[3]	0.0090 ± 0.0064	0.0077 ± 0.0028	0.0083 ± 0.0125
$C_{emitted}$[3]	0.0002 ± 0.0001	0.0002 ± 0.0001	0.0002 ± 0.0001
$C_{emitted}/C_{input}$ (%)	2.17	2.53	2.35
$C_{emitted}/C_{fixation}$ (%)	2.22	2.60	2.41
Fixation efficiency, $C = (C_{input} - C_{emitted})/C_{input}$ (%)	97.83	97.47	97.65

Note: [1] Unit = kg per individual, [2] Unit = kg per kg of fish per day, [3] Unit = kg carbon per kg of fish per day

Table 4.14 Average of C-input, C-fixation, C-output, and C-emission in form of CO_2 and CH_4 of Nile tilapia (mean ± S.D.) in Mueang Nakhon Ratchasima district.

The size of farm	Amount C transferred from feed to fish (kg.C/kg.fish/day)			0.0060 ± 0.0075
<1 rai	Carbon fixation (kg.C/kg.fish/day)	Meat		0.0038 ± 0.0038
		Bone and visceral organs		0.0020 ± 0.0036
		Total C accumulated in body (mass equilibrium)		0.0058 ± 0.0074
	Carbon emission (kg.C/kg.fish/day)	Dry faeces		0.0001 ± 0.0001
		C-emission of CO_2 and CH_4	Faeces	0.0001 ± 0.0000
			Digestion and respiration	0.000002663 ± 0.000017202
		Total C-emission from fish		0.0002 ± 0.0001
	Amount C transferred from feed to fish (kg.C/kg.fish/day)			0.0074 ± 0.0049
1 - 5 rais	Carbon fixation (kg.C/kg.fish/day)	Meat		0.0066 ± 0.0047
		Bone and visceral organs		0.0006 ± 0.0001
		Total C accumulated in body (mass equilibrium)		0.0072 ± 0.0048
	Carbon emission (kg.C/kg.fish/day)	Dry faeces		0.0001 ± 0.0001
		C-emission of CO_2 and CH_4	Faeces	0.0001 ± 0.0000
			Digestion and respiration	0.000002451 ± 0.000015214
		Total C-emission from fish		0.0002 ± 0.0001

Table 4.14 Average of C-input, C-fixation, C-output, and C-emission in form of CO_2 and CH_4 of Nile tilapia (mean ± S.D.) in Mueang Nakhon Ratchasima district (Continued).

The size of farm	Amount C transferred from feed to fish (kg.C/kg.fish/day)			0.0085 ± 0.0126
>5 rais	Carbon fixation (kg.C/kg.fish/day)	Meat		0.0064 ± 0.0101
		Bone and visceral organs		0.0019 ± 0.0024
		Total C accumulated in body (mass equilibrium)		0.0083 ± 0.0125
	Carbon emission (kg.C/kg.fish/day)	Dry faeces		0.0001 ± 0.0000
		C-emission of CO_2 and CH_4	Faeces	0.0001 ± 0.0000
			Digestion and respiration	0.000001179 ± 0.000003054
		Total C-emission from fish		0.0002 ± 0.0001

Table 4.15 Average of C-input, C-fixation, C-output and C-emission in form of CO_2 and CH_4 of Nile tilapia (mean ± S.D.) in Pak Thong Chai district.

The size of farm	Amount C transferred from feed to fish (kg.C/kg.fish/day)			0.0092 ± 0.0065
<1 rai	Carbon fixation (kg.C/kg.fish/day)	Meat		0.0073 ± 0.0050
		Bone and visceral organs		0.0017 ± 0.0014
		Total C accumulated in body (mass equilibrium)		0.0090 ± 0.0064
	Carbon emission (kg.C/kg.fish/day)	Dry faeces		0.0001 ± 0.0000
		C-emission of CO_2 and CH_4	Faeces	0.0001 ± 0.0000
			Digestion and respiration	0.000001595 ± 0.000004401
		Total C-emission from fish		0.0002 ± 0.0001
	Amount C transferred from feed to fish (kg.C/kg.fish/day)			0.0079 ± 0.0029
1 - 5 rais	Carbon fixation (kg.C/kg.fish/day)	Meat		0.0056 ± 0.0018
		Bone and visceral organs		0.0021 ± 0.0010
		Total C accumulated in body (mass equilibrium)		0.0077 ± 0.0028
	Carbon emission (kg.C/kg.fish/day)	Dry faeces		0.0001 ± 0.0000
		C-emission of CO_2 and CH_4	Faeces	0.0001 ± 0.0001
			Digestion and respiration	0.000001293 ± 0.000003808
		Total C-emission from fish		0.0002 ± 0.0001

Table 4.15 Average of C-input, C-fixation, C-output and C-emission in form of CO_2 and CH_4 of Nile tilapia (mean ± S.D.) in Pak Thong Chai district (Continued).

The size of farm	Amount C transferred from feed to fish (kg.C/kg.fish/day)			0.0060 ± 0.0075
>5 rais	Carbon fixation (kg.C/kg.fish/day)	Meat		0.0038 ± 0.0038
		Bone and visceral organs		0.0020 ± 0.0036
		Total C accumulated in body (mass equilibrium)		0.0058 ± 0.0074
	Carbon emission (kg.C/kg.fish/day)	Dry faeces		0.0001 ± 0.0001
		C-emission of CO_2 and CH_4	Faeces	0.0001 ± 0.0000
			Digestion and respiration	0.000002663 ± 0.000017202
		Total C-emission from fish		0.0002 ± 0.0001

Table 4.16 Average of carbon emission in the form of carbon dioxide (CO_2) and methane (CH_4) from Nile tilapia (mean ± S.D.).

Province	Mean of gas from	The size of farm (rai)	CH_4		CO_2		Ratio $CH_4 : CO_2$	
Mueang Nakhon Ratchasima district	Feaces	<1	0.00007 ± 0.00004	0.00007 ± 0.00004	0.00016 ± 0.00007	0.00026 ± 0.00010	0.42	**0.13**
		1 - 5	0.00008 ± 0.00001		0.00017 ± 0.00003			
		>5	0.00020 ± 0.00005		0.00044 ± 0.00011			
	Digestion and respiration	<1	0.000000 ± 0.000000	0.00000 ± 0.00000	0.000001 ± 0.000004	0.000001 ± 0.000004	0.02	
		1 - 5	0.000000 ± 0.000000		0.000002 ± 0.000015			
		>5	0.000000 ± 0.000000		0.000003 ± 0.000012			
Pak Thong Chai district	Feaces	<1	0.00007 ± 0.00003	0.00012 ± 0.00005	0.00016 ± 0.00007	0.00026 ± 0.00010	0.46	**0.15**
		1 - 5	0.00009 ± 0.00006		0.00019 ± 0.00012			
		>5	0.00020 ± 0.00005		0.00044 ± 0.00011			
	Digestion and respiration	<1	0.000000 ± 0.000000	0.00000 ± 0.00000	0.000003 ± 0.000017	0.000003 ± 0.000015	0.03	
		1 - 5	0.000000 ± 0.000000		0.000002 ± 0.000015			
		>5	0.000000 ± 0.000000		0.000004 ± 0.000012			

Note: Unit = kg carbon per kg of fish per day.

The Food and Agriculture Organization of the United Nations (FAO) (2009) reported that aquaculture production, compared to other animal husbandry practices, has a small overall CO_2 emission. The largest part of fishery production is based on freshwater species such as carp, requiring small amounts of fertilizer, often organic and in some cases, low-energy supplementary feeds. Although some species and systems, such as shrimp, salmon and marine carnivores, are a minor part of total production, they have high feed energy or system energy demands and consequently higher footprints. The global warming potential (GWP) of CH_4 is estimated to be 21 times that of carbondioxide (CO_2) and nitrous oxide (N_2O) almost 310 times that of CO_2 (IPCC, 2001). Therefore, it can be concluded that a Nile tilapia had more contribution to the cause of global warming due to the CO_2 and CH_4 emissions.

Burg van den, Taal, Boer de, Bakker, and Viets (2012) reported GHG emission of fishery systems that the methane formation occurred in an anaerobic environment, mainly in mud layers in fishery ponds. In many cases, the fish toss the soil, so an anaerobic environment does not exist, but in Nile tilapia eultivation was different. Nitrous oxide (N_2O) was released during microbial transformation of nitrogen in the soil or in manure (i.e. nitrification of NH_3 into NO_3^- and incomplete denitrification of NO_3^- into N_2) as well as during nitrate fertilizer production for feed ingredients.

4.4.2 Carbon transfer of selected districts of Nakhon Ratchasima provinces

The UNECE (2004) explained that the emission of carbon by Principle Conservation of Mass which could tell total carbon emission from the production of 1 kg live-weight for Nile tilapia is shown as follow:

$$C\text{-emitted(aquatic animal)} = (0.0001)\ \text{Nile tilapia} \quad (4.10)$$

Where:

C-emitted(aquatic animal) = Total carbon emission from Nile tilapia bodies (ton carbon per year).

Nile tilapia = Weight of Nile tilapia (kg).

The results of the rate of carbon transfer from fishery feed to each fish by food consumption (C_{input}) and then later fixed in fish bodies and organs ($C_{fixation}$), as well as the carbon content from animal faeces excreted and carbon in the form of CO_2 and CH_4 from digestion and respiration of fish ($C_{emitted}$) during rearing duration for fish are shown in Table 4.19 and Table 4.20.

The results from regression analysis can be summarized the relationship between C-emitted and C-input for Nile tilapia of Mueang Nakhon Ratchasima and Pak Thong Chai districts at Nakhon Ratchasima province are shown in the regression equations 4.11 and 4.12.

$$C\text{-emitted fish}_{(Pak\ Thong\ Chai)} = 0.006\ (C\text{-input fish food}) \quad (4.11)$$

Where:

C-emitted fish$_{(Pak\ Thong\ Chai)}$ = Carbon emitted from Nile tilapia in Pak Thong Chai district (kg.C/kg. fish/day).

C-input fish feed = Carbon content in fish feed which transferred to Nile tilapia by consumption with average value at 0.0086 ± 0.0009 (kg.C/kg.fish/day).

$$\text{C-emitted fish}_{(\text{Mueang Nakhon Ratchasima})} = 0.005\ (\text{C-inputfish feed}) \qquad (4.12)$$

Where:

C-emitted $\text{fish}_{(\text{Mueang Nakhon Ratchasima})}$ = Carbon emitted from Nile tilapia in Mueang Nakhon Ratchasima district (kg.C/kg.fish/day).

C-input fish feed = Carbon content in fish feed which transferred to Nile tilapia by consumption with average value at 0.0085 ± 0.0000 (kg.C/kg.fish/day).

According to the Principle of Conservation of Mass, carbon fixation in Nile tilapia body (C-fixation) at 1 kg live-weight per day is carbon in the form of feed consumption (C-input) minus the carbon emitted from faeces, digestion and respiration (C-emission). All carbons which accumulated in Nile tilapia body each day are used for a normal life and metabolism of the body to create new tissues. The balance of minerals and water within Nile tilapia body. The movement of food in the digestive system, respiratory, circulation, nerve function, reproductive, temperature regulation, and the movement of Nile tilapia require energy. Nile tilapia use several physiological and behavioral mechanisms to maintain their body temperature and minimize the loss of energy.

De Silva and Anderson (1995) have described how animals get energy by food consumption, which the energy appears in the form of chemical bond in molecules, protein, carbohydrates and fats. Thus, each animal has the ability to obtain energy from different kinds of food. A protein is the main organic component of aquatic animal tissues including to being used for growth and repair of tissues. Protein is also used extensively for providing energy in routine metabolism by aquatic animal (Guillaume, Kaushik, Bergot, and Metailler, 2004). It is therefore, an essential nutrient for both maintenance and growth. Comparison of the percentage of average carbons fixed in aquatic animals per average carbon content in animal feed for each aquatic animal per day (Cfixation/Cinput) showed that Nile tilapia fixed 97.08% carbon from aquatic food (Table 4.17).

The results of the fixation rates from animal feed to aquatic animals by consumption in raising duration and the Principle of Mass Conservation (UNECE, 2004) can be shown in different formula in Nile tilapia as follows:

C-input = (0.0028) Nile tilapia (4.13)

C-fixation = (0.0027) Nile tilapia (4.14)

Where:

C-input = Carbon massflow from feed to Nile tilapia by consumption of each Nile tilapia in utilized age (ton carbon per year).

C-fixation = Carbon fixation in each Nile tilapia body (ton carbon per year).

Nile tilapia = Weight of Nile tilapia (kg).

Table 4.17 Ratio of total meat, bone, and visceral organs in each aquatic animal (mean ± S.D.).

Animal	**Districe**	**Total meat (%)**	**Bone, and visceral organs (%)**	**Cfixation/Cinput (%)**	
Nile tilapia	Mueang Nakhon Ratchasima	84.400 ± 2.608	15.600 ± 2.608	97.66	97.08
	Pak Thong Chai	86.359 ± 2.481	15.287 ± 2.471	95.95	

The relationships between carbon input to aquatic animals by food consumption and carbon fixation in each aquatic animal can be shown in the formula 4.15 - 4.16 at 95% confidence ($p \leq 0.05$).

$$\text{C-fixation fish}_{\text{(Mueang Nakhon Ratchasima)}} = 0.085\ (\text{C-input Nile tilapia feed}) + 0.01 \qquad (4.15)$$

Where:

$\text{C-fixation fish}_{\text{(Mueang Nakhon Ratchasima)}}$ = Carbon fixation from Nile tilapia in Mueang Nakhon Ratchasima district (kg.C/kg.Nile tilapia/day).

C-input Nile tilapia feed = Carbon content in fish feed which transferred to Nile tilapia by consumption with average value at 0.0011 ± 0.0003 (kg.C/kg.Nile tilapia/day).

C-fixation fish $_{(Pak\ Thong\ Chai)}$ = 1.035 (C-input Nile tilapia feed) + 0.001 (4.16)

Where:

C-fixation fish $_{(Pak\ Thong\ Chai)}$ = Carbon fixation from Nile tilapia in Pak Thong Chai district (kg.C/kg. Nile tilapia/day)

C-input fish feed = Carbon content in Nile tilapia feed which transferred to Nile tilapia by consumption with average value at 0.0014 ± 0.0004 (kg.C/kg.Nile tilapia/day).

Nevertheless, the proportion of carbon contents from feed which are transferred to each aquatic animal and fixed into parts of animal body and faeces including carbon in the form of CO_2 and CH_4 from the digestion and respiration per kg of aquatic animal per day. Carbon content at 100 parts in feed was fixed in Nile tilapia at 79.92%. The rest of carbon content was released from Nile tilapia through the excretion of waste, respiration and digestion at 20.08%. This carbon is an important part in causing the harmful environmental impacts. Therefore, it can be concluded that Nile tilapia fixed the most amount of carbon in their bodies and released the least amount of carbons. Hence, Nile tilapia production can create environmental impacts.

4.5 Amount of carbon emission from energy use in Nile tilapia farm, hatchery and market

The survey in farms, hatcheries and markets in Nakhon Ratchasima province found that Nile tilapia farms had used much energy for raising Nile tilapia per day. Most of energy was used for Nile tilapia meat production such as electricity for water pumps, lighting and aeration, fuel energy for water pumps and aeration including liquefied petroleum gas (LPG) for aeration. Aeration systems helps maintain adequate dissolved oxygen (DO) concentrations of at least 6 mg/L. Carbon dioxide (CO_2) concentrations should be kept at less than 25 mg/L for best Nile tilapia growth. Aeration is the uptake of oxygen from the atmosphere into water and oxygenation is the transfer of oxygen gas to water.

Throughout, the cycle farmers either regularly managed water or used treatment only at times of poor water quality. Furthermore, energy was used for transporting Nile tilapia food and LPG to farms and hatcheries including transport of Nile tilapia product to markets or processing plants. The calculated carbon emission for the production of 1 kg Nile tilapia is shown in Table 4.18. Nile tilapia emitted carbon at 5.63 kg.C/kg.Nile tilapia/day. Most of energy used for transportation of small fish, fish feed and LPG to farms as well as transports of fish products to markets or processing plants.

Table 4.18 Average of C-emission from energy consumption in farm, hatchery and market of Nile tilapia (mean ± S.D.).

Average carbon from energy use		Average carbon from energy use Nile tilapia
Farm	Electricity	0.27835 ± 0.26380
	Fuel for transportation	16.01955 ± 11.38632
	Fuel for machine	0.00403 ± 0.00402
	LPG	0.00410 ± 0.00654
	Total C from energy/1 kg fish/day	16.30603
Market	Electricity	0.00662 ± 0.00622
	Fuel for transportation	11.35943 ± 10.50312
	LPG	0.01206 ± 0.00955
	Total C from energy/1 kg fish/day	11.37811
Total Cemission from energy of two sources (kg.C/kg.fish/day)		27.68414

The hatchery used few of energy for transporting fish feed including water pumps, light and aeration. Carbon emission from these parts is shown in Figure 4.7.

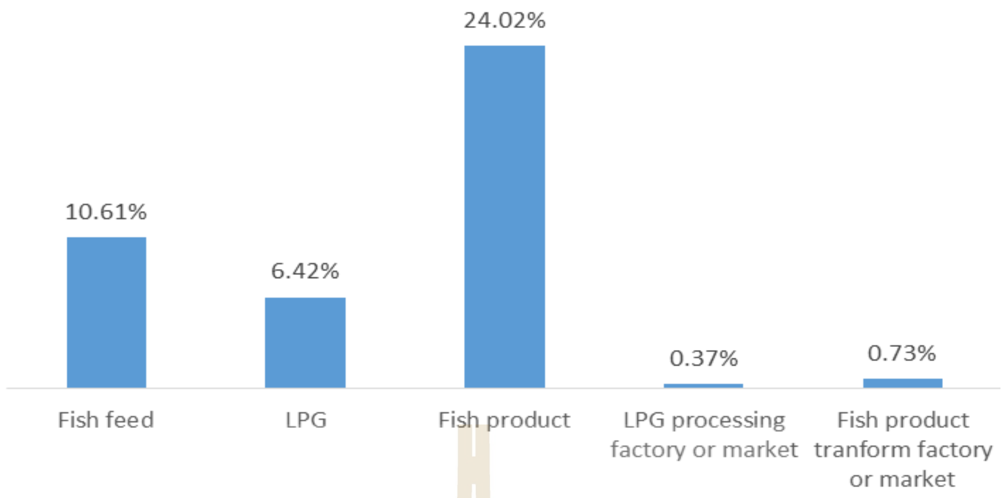

Figure 4.7 Proportion of energy used for transportation in Nile tilapia production.

However, motorcycles fuel and gasoline were used on aquaculture farms to provide transportation for many tasks, e.g., nightly dissolved oxygen monitoring, aerator maintenance, worker transport and supervision, aquatic animal health evaluation, and off-farm errands related to aquatic animal production, etc. Some farms also used small trucks for transporting supplies on farms. Data were not available for quantities of gasoline used in motorcycles and small trucks. According to Mungkung (2005) concluded an environmental LCA of shrimp farming in Thailand, which included hatchery, farming, processing, distribution, consumption, and waste management phases. The functional unit was a standard consumer-package size containing 3 kg of block-frozen shrimp. Farming was the key life cycle stage contributing to the environmental impacts. These impacts arose mainly from the use of energy, shrimp food, chemical and burnt lime. Transport of post larvae study by Pelletier and Tyedmers (2010), who concluded that important factors influencing the GHGs emission of seafood production were come from the use of energy during production, processing, storage and transportation of raw materials in hatcheries, farms and processing plants includes the distribution of aquatic products to consumers, from non-local sources to farms also resulted in significantly higher impacts. Another study by Pelletier and Tyedmers (2010), who concluded that important factors influencing the GHGs emission of seafood production were come from the use of energy during production, processing, storage and transportation of raw materials in hatcheries, farms and processing plants include the distribution of aquatic products to consumers. With regard to transport, it was found that an important factors influencing the GHGs emissions of aquatic products transport included the transport mode (i.e., truck, pickup, ship, train or aircraft), the size of the vehicle, speed, load capacity, transportation time, need for refrigeration, and distance (Mungkung, Udo de Haes, and Clift, 2006; Ziegler et al., 2012).

Moreover, the electricity requirements of equipment at the Nile tilapia farms, hatcheries and markets for Nile tilapia was 930.87 kWh/kg. Nile tilapia. Hatcheries used most of electricity energy for water pumps, light and aeration.

4.6 Carbon content in fish feed, meat and faeces including analysis of environmental impacts from Nile tilapia production

The results of average dry weight of fish feed, meat and dry faeces which were explored by the amount of fish feed consumption and faeces excreted in one day per individual including average living aquatic animal weight from all aquaculture farms could get the ratio of relationship between dry faeces weight per average dry weight of fish feed per day. A Nile tilapia released the highest faeces at 34.24% of fish food (Table 4.19 - 4.20). This is positively correlated with the relationship between carbon consumption (C-input) and carbon emission from Nile tilapia (C-emitted) at 95% confidence.

Figure 4.8 shows the carbon content in Nile tilapia feed, meat and faeces. The Nile tilapia accumulated carbon in bodies at 49.64%,. This is another reason to support that Nile tilapia farms create few environmental impacts because a Nile tilapia is capable to accumulate carbon (C-fixation) in the bodies better.

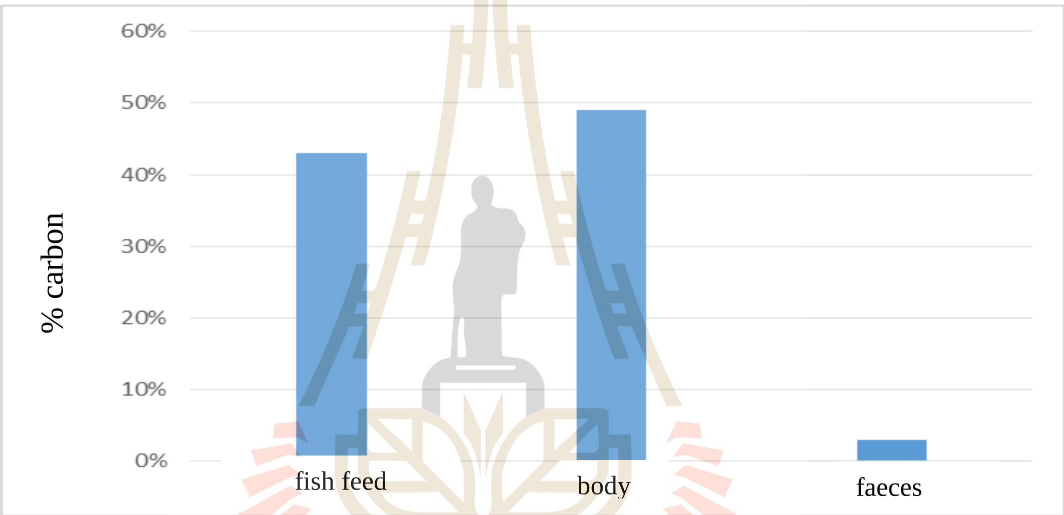

Figure 4.8 Percentage of carbon content in fish feed, body and faeces of Nile tilapia.

Table 4.19 Average and relationship between carbon, dry weight of Nile tilapia feed and faeces excreted from Nile tilapia per day was compared at 1 kg live-weight of Nile tilapia (mean ± S.D.).

Average and relationship	**Nile tilapia**
Average rearing duration (day)	300.34483 ± 184.85886
Live fish weight (kg/ind)	2.29793 ± 1.20942
Dry fish feed for fish consumption (kg/ind/day)	0.01020 ± 0.01055
Dry fish feed for fish consumption (kg/kg.fish/day)	0.01851 ± 0.02101
Dry faeces (kg/ind/day)	0.00333 ± 0.00323
Dry faeces (kg/kg.fish/day)	0.00482 ± 0.00419
Dry weight of fish feed consumption per live fish weight	4.253%
Dry weight of faeces per live fish weight	11.075%
Dry weight of faeces per dry weight of fish feed consumption	26.040%
C in the form of CO2 and CH4 per C in fish feed	1.150%
C in fish faeces per C in fish feed	0.506%

Table 4.20 Relationship between moisture, volatile solid and carbon content of fish feed, faeces, meat and entrails of Nile tilapia (mean ± S.D.).

Animal	Data type	Moisture (%)	Ash (%)	Total volatile solid (%)	Carbon content (%C)	Relationship between %TVS and %C	R^2
Nile tilapia	feed	55.620 ± 30.165	74.294 ± 3.550	71.281 ± 4.611	42.705 ± 2.689	%TVS = 0.183(%C) + 79.081	0.110
	Faeces	50.370 ± 4.279	60.277 ± 5.791	39.107 ± 9.247	1.802 ± 0.578	%TVS = 2.074(%C) + 35.368	0.170
	Meat	75.318 ± 4.243	80.870 ± 0.839	79.168 ± 3.592	49.516 ± 1.128	%TVS = 0.269(%C) + 92.507	0.070
	Bone	65.183 ± 2.532	68.173 ± 1.915	69.933 ± 4.786	34.529 ± 1.175	%TVS = 2.421(%C) - 13.656	0.354
	visceral organs	62.542 ± 6.242	92.069 ± 6.683	91.392 ± 7.438	37.278 ± 1.336	%TVS = 0.713(%C) + 64.796	0.160

4.7 Environmental impacts, perception and adoption of alternative systems

The results of carbon emissions into the atmosphere from fishery production found throughout the process of producing animal to consumers. Carbon emitted into the atmosphere due to the use of energy such as electricity, fuel and LPG especially for transportation. Therefore, the consideration to reduce carbon emissions should focus on the issue of reducing energy consumption or modification guidelines for energy efficiency, which can reduce the amount of carbon emissions from the production of Nile tilapia. For instance, the range of fishery farming, the farmers should use LPG as the energy source to aeration instead of the use of fuel (diesel). LPG has a higher efficiency in the combustion process including create less ash and environmental impacts than diesel oil. Additionally, LPG releases heat energy about 11,832 - 12,034 Kcal/kg equivalent to electricity at 13.70 kWh/kg (Vichit-Vadakan et al., 2001).

Moreover, a guidelines to reduce carbon emissions from energy used for transportation of fishery feed, young fish, and LPG to farm and hatchery including transport of fishery products to market should be considered. The result showed that this sector had the most of energy consumption and highest carbon emission. So, it can be recommended that farmers should reduce the distance and reduce the number of trips for transportation, for example farmer should buy fishery feed and LPG within the province or neighborhood farms. Additionally, another way for the reduction of carbon emission from the production of Nile tilapia should guide and encourage the farmers for aquatic meat production should be proceeded.

A vast majority of farmers have not utilized any type of water treatment prior to discharging water into public canals and waterways. This combined with intensive production that utilizes protein rich diets has the potential to significantly degrade water quality in the natural canals and waterways used by multiple users. While water treatment systems could mitigate current and future environmental problems, it is necessary that these systems optimally balance adequate environment. From an environmental standpoint, impacts of intensive farming systems will only become exacerbated if the discharge of untreated effluent continues. New (2002) states that recognition of responsible aquaculture should include attention to the discharge of polluted effluents into natural waterways. So, the water treatment holds a guarantee in completely avoiding the release of waste water from aquaculture, where the environmental impact towards eutrophication is relatively non-existent (Ayer and Tyedmers, 2009).

It is also important to notice that fishery production is not restricted to the mentioned impacts; rather there are several fishery specific impacts that need to be considered. These fishery specific impacts (e.g. disease transfer, water use, etc.) have been the main problem considered in classical environmental impact assessments of fishery. However, until now these impacts have proven difficult in characterization and are generally ignored studies. Therefore, further research is urgently required in understanding and characterization of these impacts in fishery.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The comparative studies of the carbon massflow, carbon fixation, carbon emission from Mueang Nakhon Ratchasima, Kham Thale So, Sung Noen and Pak Thong Chai districts for Thai native chicken and Mueang Nakhon Ratchasima and Pak Thong Chai districts of Nakhon Ratchasima province for Nile tilapia (*Oreochromis niloticus*). The durations of studies were between October 2013 and September 2014.

The chapter V conclusions and recommendations is separated into two parts, Part I is concerned about Thai native chicken and Part II is Nile tilapia, respectively.

Part I Thai native chicken

The study of carbon emission per day from Thai native chicken production was 0.016 ± 0.59 kg C/Thai native chickens/day. Meanwhile, efficiency of carbon fixation was 64.79% of overall carbon released and most of emitted carbon was in form of carbon dioxide (CO_2) and methane (CH_4) which was released from respiration and excretion processes. The energy used in Thai native chicken meat production released 35.593×10^{-3} kg.C/Thai native chickens/day. Hence, the study of carbon emissions into the atmosphere from native chicken farming was found throughout the whole production process of native chicken meat.

To consumers, all carbon emissions into the atmosphere due to energy consumption. Specifically, the use of energy for transportation, so that, in consideration for reducing carbon emissions, attention should be paid to the issue of reducing energy consumption or energy use. This can reduce carbon emissions for native chicken production.

Part II Nile tilapia

The study of carbon emission per day from Nile tilapia the resule found that Nile tilapia fixed carbon was 75% of overall carbon released and the ratio of carbon emitted was 0.0001 ± 0.0001 kg.C/kg Nile tilapia/day in fish production. Furthermore, carbon emission from the use of energy in Nile tilapia farms was 11.66323 kg.C/kg Nile tilapia/day. While, the most of carbon emissions per day of aquatic animals were found in faeces and Nile tilapia emitted carbon in the form of CO_2 and CH_4 at 15.96% Comparison of the percentage of average carbon fixation into body and organs of aquatic animals per average carbon input from aquatic food to these aquatic animals. The food consumption per day (C-fixation/C-input) found that a Nile tilapia fixed carbon at 79.92% from aquatic food.

The results of this study showed that most carbon emission from Thai native chicken and Nile tilapia productions were from energy used such as electricity, fuel and LPG particularly energy fuel used for transportation. Therefore, the reduction of carbon emissions should focus on the issue of reducing energy consumption and modification guidelines for energy efficiency, which can reduce the amount of carbon emissions from the production of Thai native chicken and Nile tilapia as follows:

(1) Ranking and selection of aquatic animal kind that should guide and encourage the farmers for aquatic meat production. The results of this study should encourage the Nile tilapia culture because the proportion of all carbon emissions including individual and energy consumption to Thai native chicken and Nile tilapia meat proportions.

(2) Farmers should use LPG as the energy source to aeration instead of the use of diesel oil due to LPG had a higher efficiency in the combustion process including created less ash and environmental impacts than diesel oil.

(3) Farmers should reduce distance and reduce the number of trips for transportation such as the farmer should buy aquatic food and LPG within the province or neighbourhood with Nile tilapia farm. Moreover, they should plan the use of aquatic food, LPG and other raw materials to reduce the number of trips for transportation in aquaculture processes.

5.2 Recommendations

Thai native chicken and Nile tilapia farming are increasing trend in Thailand especially in provinces that locate on the coastal areas in the eastern and north eastern parts of Thailand. Besides, Thai native chicken and Nile tilapia farming, there are also other livestock and aquaculture farming such as giant tiger prawn, Asian green mussel, oyster, walking catfish, swine, goats, pekin ducks, laying ducks and three breed-cross native chicken, etc. Further investigation should be focused on the study of carbon massflow from these livestock and aquaculture farming to be used as a data for carbon transfer and carbon emission from Thai native chicken and Nile tilapia meat productions including the development of the carbon footprint in Thailand This study focused on Thai native chicken and Nile tilapia farms, hatchery and market only, which it does not cover the entire process of Thai native chicken and Nile tilapia meat productions. Therefore, the Thai native chicken and Nile tilapia food production processes should be investigated in future studies.

REFERENCES

REFERENCES

APHA, AWWA, and WEF. (2005). **Standard methods for the examination of water and wastewater**. 21th Edition. Washington D.C., USA: American Public Health Association.

Ayer, N. W., and Tyedmers, P. H. (2009). Assessing alternative aquaculture technologies: Life cycle assessment of salmonid culture systems in Canada. **Journal of Cleaner Production**. 17: 362-373.

Bos, J. F. F. P., and de Wit, J. (1996). **Environmental impact assessment of landlessmonogastric livestock production systems**. Working Document Livestock and the Environment: Finding a Balance. FAO/World Bank/USAID, Rome.

Boyd, C. E. (1995). **Bottom soils sediment and pond aquaculture**. 1st edition. New York: Chapman & Hall. 350p.

Brandjes, P. J., de Wit, J., van der Meer, H. G., and Van Keulen, H. (1996). **Livestock andthe environment finding a balance**. Environmental Impact of Animal Manure Management. International Agriculture Centre, Wageningen, Netherlands.

Brody, S. (1945). **Bioenergetics and growth**. New York: Hafner.

Bunyavejchewin, P., Rompopak, W., Vechabusakorn, O., Khumnerdpetch, W., Pikulthong, P., and Chantalakhana, C. (1985). Comparative efficiency of tapes for estimation of weight of swamp buffaloes and cattle.

Annual Report 1985. The National Buffalo Research and Development Center Project. Bangkok, Thailand.

Burg van den, S. W. K., Taal, C., Boer de, I. J. M., Bakker, T., and Viets, T. C. (2012). **Environmental performance of wild-caught North Sea whitefish: A comparison with aquaculture and animal husbandry using LCA**. Den Haag: LEI Wageningen UR. 53p.

Burrows, S. M. (2014). **A physically based framework for modeling the organic fractionation of sea spray aerosol from bubble film Langmuir equilibria** [On-line]. Avalable: https://www.atmos-chem-phys.net/14/13601/2014/acp-14-13601-2014.pdf.

Buswell, A. M., and Mueller, H. F. (1952). Mechanisms of methane fermentation. **Industrial Engineering Chemistry**. 44: 550-552.

Casey, T. J. (1981). Developments in anaerobic digestion. **Transactions of the Institute of Engineers in Ireland**. 105: 25-32.

Cavana, R. Y., Delahaye, B. L., and Sekaran, U. (2000). **Applied business research: qualitative and quantitative methods**. New York: John Wiley and Sons.

CNPP THAILAND. (2013). Country nuclear power profiles [On-line]. Available: http //:www.pub.iaea.org/MTCD/Publications/PDE/CNPP2013CD/countryprofiles/ Thailand/Figures/CNPP%20THAILAND%202013.pdf.

De Haan, C., Steinfeld, H., and Blackburn, H. (1997). **Livestock and the environment finding a balance**. E.U. Development Policy Sustainable Development and Natural Resources. U.K.: WREN Media Eye.

De Silva, S. S., and Anderson, T. A. (1995). **Fish nutrition in aquaculture**. London: Chapman and Hall. 384p.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., and Courbois, C. (1999). **Livestock to 2020: The next food revolution**. Food, Agriculture and Environment Discussion Paper 28. Washington DC: International Food Policy Research Institute.

Department of Livestock Development. (2009). **Bureau of livestock standards and certification** [On-line]. Avalable: http://www.dld.go.th/ict.

Department of Livestock Development. (2009). **Development of Thai native chicken (Pradu-Hangdum Chiangmai): From the community to the hi-end market** [On-line]. Available: http://www.thainative chicken.com/web/?name=page&file=page&op=native%20chicken.

Department of Livestock Development. (2009). **Livestock data** [On-line]. Available: http://www.dld.go.th/index.html.

Fleischhauer, E., Bayer, W., and Von, Lossau, A. (1997). Assessing and monitoring environmental impact and sustainability of animal production. In: **Proceedings of the International Conference on Livestock and the Environment**. Held in Ede/Wageningen, the Netherlands 16-20 June 1997, organized by World Bank Food and Agriculture Organization International Agricultural Centre.

Fishery Office in Nakhon Ratchasima. (2015). [On-line]. Available: http://www.fisheries.go.th/ifkorat/index.php?option=com_content&view=article&id=52&Itemid=109.

Food and Agriculture Organization of the United Nation (FAO). (1990). The technology of traditional milk products in developing countries. **FAO Animal Production and Health**. Rome. pp. 85.

Food and Agriculture Organization of the United Nation (FAO). (2006). **Livestock's long shadow** [On-line]. Available: http//www.fao.org/docrep/010/a070e00.html.

FAO. (2009). **The state of world fisheries and aquaculture 2008 (SOFIA)**. Rome: Electronic Publishing Policy and Support Branch. 196p.

Gavrilova, O., Jonas, M., Erb, K., and Haberl, H. (2010). International trade and Austria's livestock system: Direct and hidden carbon emission flows associated with production and consumption of products. **Ecological Economics**. 69: 920-929.

Guérin, H., Richard, D., Lefevre, P., Friot, D., and Mbaye, N. (1989). **Prévision de lavaleur nutritive des fourrages ingérés sur parcours naturels par les ruminants domestiques sahéliens et soudaniens**. **In: XVIth International Grassland Congress**. **Institut National de la Recherche Agronomique**. pp. 879-880. 4-11October. France: Nice.

Guillaume, J., Kaushik, S., Bergot, P., and Metailler, R. (2004). **Nutrición yalimentación de peces y crustáceos**. Madrid: Mundi-Prensa. 475p.

Hanzade, H-A., Aysegul, E-M., and Sadriye, K. (2001). Effect of mineral matter on the reactivity of lignite chars. **Energy Conversion and Management**. 42: 11-20.

Herrero, M., Thornton, P. K., Gerber, P., and Reid, R. S. (2009). Livestock, livelihoods and environment: Understanding the trade-offs. **Current Opinion in Environmenttal Sustainability**. 1: 111-120.

Ickowicz, A., Richard, D., and Usengumuremyi, J. (1999). Estimation of organic matter transfers by cattle in a Senegalese village. In: **Proceedings of the VI th**

International Rangeland Congress. pp. 500-502. 19-23 July. Australia: Townsville.

International Fund for Agricultural Development (IFAD). (2004). **Livestock services and the poor**. International Fund for Agricultural Development Printed in Rome, Italy: Ugo Quintily S.P.A.

Intergovernmental Panel on Climate Change (IPCC). (1995). **Climate change 1995, the science of climate change**. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Syndicate of the University of Cambridge, Cambridge, U.K. p. 572.

Intergovernmental Panel on Climate Change (IPCC). (2001). **Climate change 2001, The scientific basis**. The Third Assessment Report of the Intergovern-mental Panel on Climate Change. Cambridge, UK: Press Syndicate of the University of Cambridge United Kingdom.

Intergovernmental Panel on Climate Change (IPCC). (2007). **Climate change-Greenhouse gas emission** [On-line]. Available: http//www.epa.gov/climate change/emission/usinven-toryreport.html.

Intergovernmental Panel on Climate Change (LPCC). (2007). **A report of Working Group I of the Intergovernmental Panel on Climate Change: Summary for Policymakers** [On-line]. Available: https://www. ipcc. ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf.

Kawashima, T., Kurihara, M., Sumamal, W., Pholsen, P., Chaithiang, R., and Boonpakdee, W. (2000). Comparative study on rumen physiology between Brahman cattle and swamp buffalo fed with Ruzi grass hay with or without filter cake and rice bran mixture. **Improvement of cattle production with locally available feed resources in Northeast Thailand**. pp. 67-73.

Kawashima, T., Terada, F., and Shibata, M. (2000). Respiration experimental system. In: Japan International Research Center for Agricultural Sciences, **Improvement of cattle production with locally available feed resources in Northeast Thailand**. pp. 1-21.

Keeratiurai, P., Thanee, N., and Vichairattatragul, P. (2013). Assessment of the carbon massflow from the layer farming with life cycle inventory. **ARPN Journal of Agricultural and Biological Science**. 8(9): 673-682.

Liang, J. B., Terada, F., and Hamaguchi, I. (1989). Efficacy of using the face mask technique for the estimation of daily heat production of cattle. In: van der Honig, Y., and Close, W. H. (eds.). **Energy metabolism of farm animals**. Wageningen: Pudoc. pp. 348-351.

Lippke, B., Wilson, J., Perez-Garcia, J., Bowyer, J., and Meil, J. (2004). CORRIM: life-cycle environmental performance of renewable building materials. **Forest Products**. 54(6): 8-19.

Manlay, R. J., Chotte, J. L., Masse, D., Laurent, J. Y., and Feller, C. (2002). Carbon, nitrogen and phosphorus allocation in agro-ecosystems of a West African savanna II. Plant and soil components under continuous cultivation. **Agriculture Ecosystems and Environment**. 88(3): 249-269.

Manlay, R. J., Ickowicz, A., Masse, D., Feller, C., and Richard, D. (2004a). Spatial carbon, nitrogen and phosphorus budget in a village of the West African savanna-II. Element flows and functioning of a mixed-farming system. **Agricultural Systems**. 79: 83-107.

Manlay, R. J., Ickowicz, A., Masse, D., Floret, C., Richard, D., and Feller, C. (2004b). Spatial carbon, nitrogen and phosphorus budget of a village in the West African savanna-I. Element pools and structure of a mixed-farming system. **Agricultural Systems**. 79: 55-81.

Maps of world. (2015). **Thailand provinces Nakhon Ratchasima map** [On-line]. Available: http://www.mapsofworld.com/thailand/provinces/nakhonratchasimamap.html

Marks, G. R. (1982). **Designing a research project**. Belmont, California: Lifetime Learning.

Mc Dermott, J. J., Staal, S. J., Freeman, H. A., Herrero, M., and Van de Steeg, J. A. (2010). Sustaining intensification of smallhoder livestock systems in the tropics. **Livestock Science**. 130: 95-109.

Misra, K. B. (1996). **Clean production-Environmental and economic perspectives**. Berlin: Springer-Verlag.

Misra, R. V., Roy, R. N., and Hiraoka, H. (2003). **On-farm composting methods**. **FAO Land and Water Discussion Paper 2**. Food and Agricultural Organization of the United Nations, Rome.

Mungkung, R. T. (2005). **Shrimp aquaculture in Thailand: Application of life cycle assessment to support sustainable development**. Ph.D. thesis. Center for Environmental Strategy, School of Engineering, University of Surrey, United Kingdom.

Mungkung, R. T., Udo de Haes, H. A., and Clift, R. (2006). Potentials and limitations of life cycle assessment in setting ecolabelling criteria: A case study of Thai shrimp aquaculture product. **The International Journal of Life Cycle Assessment**. 11(1): 55-59.

Nakhonratchasima Provincial Livestock Office. (2013). [On-line]. Available: http://pvl o-nak.dld.go.th/data/zone/zone57/chic57.jpg,2015.

Nemry, F., Theunis, J., Brechet, T., and Lopez, P. (2001). **Greenhouse gas emissions reduction and material flows**. Institute Wallan, Federal Office for Scientific, Technical and Cultural Affairs, Belgium.

New, M. B. (2002). **Commercial freshwater prawn farming around the world**. Quoted in New, M. B., and Valenti, W. C. (Eds.). Freshwater prawn culture: The farming of *Macrobrachium rosenbergii*. London, Oxford: Blackwell Science Ltd. pp. 290-323.

Odum, E. P. (1971). **Fundamentals of ecology**. London: W.B. Saunders.

Office of Natural Resources and Environmental Policy and Planning. (1996). **Thailand's national greenhouse gas inventory** [On-line]. Available: http// www.thaiwikidata.org/wiki/index.php.

Organization for Economic Co-opeation and Development (OECD). (1997). **OECD Environmental performance reviwes-a practical introduction OCDE/GD (97)** 35 Paris 1997 [On-line]. Available: http//www.Smallstock. info/reference OECD/gd9735.pdf.

Organization for Economic Co-operation and Development (OECD). (1999). **Working group on the state of the environment. Towards more sustainable household consumption patterns: Indicators to measure progress** [On-line]. Available: http://www.smallstock.info/reference/OECD/ epocse98.pdf.

Organisation for Economic Co-operation and Development [OECD]. (2000). **Environmental indicators for agriculture methods and results**. Executive Summary. Paris, France. 53p.

Owen, E., Kitalyi, A., Jayasuriya, N., and Smith, T. (2005). **Livestock and wealth creation: improving the husbandry of animals kept by resource-poor people in developing countries**. Nottingham, UK: Nottingham University Press.

Pelletier, N. L., and Tyedmers, P. H. (2010). Life cycle assessment of frozen tilapia fillets from Indonesian lake-based and pond-based intensive aquaculture systems. **Journal of Industrial Ecology**. 14: 467-481.

Perez-Garcia, J., Lippke, B., Comnick, J., and Manriquez, C. (2005). An assessment of carbon pools, storage, and wood products market substitution using life-cycle analysis results. **Wood & Fiber Science**. 37: 140-148.

Pretty, J., Brett, C., Gee, D., Hine, R., Mason, C. F., Morison, J. I. L., Raven, H., Rayment, M., and Van de Bijl, G. (2000). An assessment of the total external costs of UK agriculture. **Agricultural Systems**. 65(2): 113-136.

Sauerbeck, D. R. (2001). CO_2 emissions and C sequestration by agriculture-perspectives and limitations. **Nutrient Cycling in Agroecosystems**. 60: 253-266.

Sere, C., and Steinfeld, H. (1996). **World livestock production systems:** Current status, issues and trends. Animal Production and Health Paper No. 127. FAO, Rome.

Smith, R. L. (1974). **Ecology and field biology**. 2nd edition. New York. Harper and Row.

Steel, R. G. D., and Torrie, J. H. (1980). **Principle and procedure of statistics**. 2nd edition. New York: McGraw-Hill. 481p.

Steinfeld, H., de Haan, C., and Blackburn, H. (1997). **Livestock-environment interactions issues and options**. E.U. Development Policy Sustainable Development and Natural Resources, WREN Media Eye, UK.

Stern, N. (2006). **The economics of climate change**. Cambridge: Cambridge University Press. 712p.

Tamminga, S. (2003). Pollution due to nutrient losses and its control in European animal production. **Livestock Production Science**. 84: 101-111.

Tantipanatip, W., Jitpukdee, S., Keeratiurai, P., Tantikamton, K., and Thanee, N. (2014). Life cycle assessment of Pacific white shrimp (*Penaeus vannamei*) farming system in Trang province, Thailand. **Advanced Materials Research**. 1030-1032: 679-682.

Tantipanatip, W., Jitpukdee, S., Keeratiurai, P., Tantikamton, K., and Thanee, N. (2015). Carbon massflow from Pacific White Shrimp (*Penaeus vannamei*) production using life cycle assessment in Songkhla Province, Thailand. **International Journal of Advances in Agricultural and Environmental Engineering**. 2(1): 13-17

TGO, Thailand Greenhouse Gas Management Organization. (2011). **Common data of carbon footprint analyzes** [On-line]. Available: http://conference.tgo.or.th/ download/tgo_ or_th/publication/CFP_Guideline_TH_Edition3.pdf.

Thanee, N., Dankitikul, W., and Keeratiurai, P. (2008). Comparison of carbon emission factors from ox and buffalo farms and slaughterhouses in meat production. In: **Proceeding of the International Conference on Energy**

Security and Climate Change: Issues, Strategies, and Option; August 6-8, 2008; Sofitel Centara Grand, Bangkok, Thailand, pp. 52-53.

Thanee, N., Dankittikul, W., and Keeratiurai, P. (2009). Comparison of carbon emitted from ox buffalo pig and chicken farms and slaughterhouses in meat production. **Suranaree Journal of Science and Technology**. 16(2): 79-90.

Thanee, N., Dankittikul, W., and Keeratiurai, P. (2009a). Comparison of carbon emitted from ox buffalo pig and chicken farms and slaughterhouses in meat production. **Suranaree Journal of Science and Technology**. 16(2): 79-90.

Thanee, N., Dankittikul, W., and Keeratiurai, P. (2009b). Comparison of carbon emitted factors from ox and buffalo farms and slaughterhouses in meat production. **Thai Journal of Agricultural Science**. 42(2): 97-107.

Udomsinrote, K. (2000). **Wastewater treatment engineering**. Forth Edition. Rangsit University.

United Nations Economic Commission for Europe (UNECE). (2004). **Task force on emission inventories and projections** [On-line]. Available: http://tfeip-secretariat.org/unece.htm.

United Nations Framework Convention on Climate Change (UNECE). (2005). **Feeling the heat**. **electronic background document-United Nations framework convention on climate change** [On-line]. Available: http://unfccc int/essential_background/feeling_the_heat/.

Upton, M. (2004). **The role of livestock in economic development and poverty reduction**. **Food and Agriculture Organization**: Pro-Poor Livestock Policy Initiative. PPLPI Working Paper No.10.

Verheijen, L. A. H. M., Wiersema, D., Hulshoff Pol, L. W., and De Wit, J. (1996). **Management of waste from animal product processing**. Working Document Livestock and the Environment: Finding a Balance. FAO/World Bank/USAID. Rome.

Vichairattanatragul, P. (2014). Carbon massflow of swine, goat, three breed-cross native chicken, puking duck and laying duck productions for carbon footprints development in Nakhon Ratchasima. Prachin Buri and Chon Buri provinces, Thailand. Ph.D. thesis. School of Biology, Institute of scicence, Suranaree University of Technology, Nakhon Ratchasima, Thailand.

Vichairattanatragul, P., Thanee N., and Keeratiurai, P. (2015). Carbon massflow and greenhouse gases emission from pork and goat meat productions in Thailand: case study of Nakhon Ratchasima, Chon Buri and Prachin Buri provinces. **Journal of Agricultural Technology**. Vol. 11(8):2333-2341.

Vichit-Vadakan, N., Ostro, D. B., Chestnut, G. L., Mills, D. M., Aekplakorn, W., Wangwongwatana, S., and Panich, N. (2001). Air pollution and respiratory symptoms:Results from three panel studies in Bangkok, Thailand. **Environmental Health Perspectives**. 109(3): 381-387.

Ziegler, F., Winther, U., Hognes, E. S., Emanuelsson, A., Sund, V., and Ellingsen, H. (2012). The carbon footprint of Norwegian seafood products on the global seafood market. **Journal of Industrial Ecology**. 17(1): 103-116.

APPENDICES

APPENDIX A

THE MULTIPLIER OF CARBON EMISSIONS FROM THE USE OF ELECTRICITY, FUEL, LIQUEFIED PETROLEUM GAS AND THE AMOUNT OF CARBON IN VARIOUS ENERGY SOURCES

Table A1 The multiplier of carbon emissions from fuel energy (stationary combustion).

Fuel type	**Unit**	**Emission factor sources ($kg.CO_2$-eq/Unit)**	**Reference**
Liquefied petroleum gas (LPG)	L	1.6812	LPCC, 2007
Liquefied petroleum gas (LPG)	kg	3.1100	LPCC, 2007
Natural gas	MJ	0.0099	LPCC, 2007
Diesel	L	2.7080	LPCC, 2007
Benzene	L	2.1896	LPCC, 2007
Coking coal	kg	2.6268	LPCC, 2007
Lignite	kg	1.0624	LPCC, 2007
Fuel oil	L	3.0883	LPCC, 2007
Fuel oil	MJ	0.0926	LPCC, 2007
Kerosene	L	2.4777	LPCC, 2007
Biomass	kg	0.6930	LPCC, 2007
Biodiesel	L	2.6265	LPCC, 2007

Table A2 The multiplier of carbon emissions from fuel energy (combustion for transportation).

Fuel type	Unit	Emission factor sources ($kg.CO_2$-eq/Unit)	Reference
Liquefied petroleum gas (LPG)	L	1.5362	IPCC, 2007
Liquefied petroleum gas (LPG)	kg	2.8400	IPCC, 2007
Natural gas (CNG)	kg	2.2472	IPCC, 2007
Diesel	L	2.7446	IPCC, 2007
Benzene	L	2.1896	IPCC, 2007
Gasohol	L	2.896	IPCC, 2007
Biomass	L	2.6265	U.S. Energy Information Administration

Table A3 Emissions from electricity generation (g/kWh).

Power plant type		CO_2	NO_2	SO_2
Commercial fuel	Coking coal	322.80	1.80	3.40
	Fuel	258.50	0.88	1.70
	Natural gas	178.00	0.90	0.001
	Nuclear	7.80	0.003	0.03
Renewable energy	Biomass	0.00	0.60	0.14
	Wind power	6.70	Very few	Very few
	Water power	5.90	Very few	Very few
	Geothermal energy	51.50	Very few	Very few

Table A4 Analysis of carbon input for electricity production at 1 kWh from the proportion of fuel energy used of Thailand in 2012.

Proportion of the Thailand's Electricity production*	**Electricity production**		**Relationship between the reaction and products**	**C-input from electricity energy use**	**Amount of CO_2 (t)**
	Ability of fuel	**Fuel density**			
Fuel oil 0.84%	11.05 kWh/L	Light oil at 15°C = 930 g/l	Fuel oil, $C_nH_{2n}+2$ (C = 14-20) = (168/198) × (930/11.05)	0.072 Kg.C_{C20H42}/kWh 0.071 Kg.C_{C14H30}/kWh	968,767
Diesel oil 0.24%	10.12 kWh/L	Diesel oil at 20°C = 850 g/l	Diesel oil (C12H26) = (144/170)×(850/10.12)	0.071 Kg.C_{C12H26}/kWh	50,904
Coking coal/ Lignite 19.28%	2.91 kWh/kg	Coking coal/Lignite** = %C = 73% by weight	1g CCH4= (2.9/667) × (16/12)	0.251 Kg.$C_{Lignite}$/kWh	17,717,652
Natural gas 66.90%	0.29 kWh/m3	1 m^3 of CH_4 = 0.667 kg at standard condition (20°C 1atm)	1 kg CCH4 = 5.783 kWh	0.173 Kg.C_{CH4}/kWh	24,597,771
Biomass 1.90%	3.52 kWh/kg	biomass*** (bagasse + chaff) = %C = 45% by weight		0.128 Kg.$C_{biomass}$/kWh	-
Water-power 10.76%				-	-
Wind power + Sun light (very few)				-	-
The use of electricity energy at 1 kWh is equal to				0.158 Kg.C/kWh	0.5610 Kg.CO2-eq/kWh

Note: * Reports and charts of electricity of Thailand in 2012 (2013) and TC Common data (2013).

** Hanzade et al. (2001).

*** Brody (1945); Maynard and Loosli (1969).

APPENDIX B

CARBON CONTENT ANALYSIS BY LECO CHN628 SERIES ELEMENTAL ANALYZER AND GAS ANALYZER

The LECO CHN628 Series Elemental Analyzer is used to determine nitrogen, carbon/nitrogen and carbon/hydrogen/nitrogen in samples such as aquatic foods, aquatic meat products and faeces (Figure B1). Prior to carbon analysis, samples are oven dried at 103 - 105°C for 24 h and grind. For carbon analysis, the samples weigh about 0.2 g was wrapped by tin foil capsule and then put it in the loading chamber about 30 samples per round. The samples were tested by incinerating at temperatures range of at least 950 - 1,050°C with pure oxygen to ensure the complete combustion of all organic samples. Rapid analysis times (4 - 5 minutes) for all the elements being determined in each sample. Additionally, the instrument features custom Windows based software operated through an external PC to control the system operation and data management.

Figure B1 LECO CHN628 Series Elemental Analyzer.

Initial setup

Open the air compressor, helium gas and oxygen gas tanks follow by LECO CHN628 Series Elemental Analyzer and PC. Click on the Software CHN628 series program icon to start the program. The Software CHN628 series Main Window appears. Select "Diagnose" from the File menu. The Main window appears; click "Furnace" from the File menu and select an automated analysis at "Control Loop Status" by setting the temperature of 950°C; and then wait for the machine to set up a system of temperature and atmospheric pressure. Each value will begin to appear in the window. Main window displays the percentage of carbon, hydrogen and nitrogen as well as the status of various CHN628 Series parameters.

The CHN analyzers are calibrated with EDTA substance that indicates the percentage of carbon, hydrogen and nitrogen of 41.06 ± 0.09, 5.55 ± 0.03 and 9.56 ± 0.03, respectively. EDTA substance, weighed about 0.2 g in tin foil capsule, are introduced into the loading chamber heated at a temperatures of 950 - 1,050°C with a constant flow of pure oxygen. Click "Configuration" from the File menu and select "Drift"; EDTA capsule is released into the furnace 1 capsule per time. Analysis of carbon emission in the form of CO_2 and CH_4 from the digestion and respiration of aquatic animals and faeces were measured by Gas Analyzer.

APPENDIX C

PUBLICATIONS

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Carbon emission from energy use in Thai native chicken production in Nakhon Ratchasima province, Thailand

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Panisara Vichiratanatrakul, Nathawut Thanee, Natthakittiya Paiboon, Watcharaporn Tantipanatip and Thanapan Thanee (YEAR) Carbon emission from energy use in Thai native chicken production in Nakhon Ratchasima province, Thailand. Journal of Agricultural Technology. Vol. 11(8):1973-1986

Abstract
The chicken production usually has impacts on the environment such as soil, water and air quality. The purposes of this research were to evaluate total carbon emission and to compare carbon emission between traditional and manufactural rairing systems in Thai native chicken production in Nakhon Ratchasima province during January to June 2015. Survey and questionnaire were made and data were collected at 400 farms in districts of study area. The results showed that the highest total carbon emission was from transportation of animal feed to farms at 10.062±4.832 kg.C/kg.Thai native chicken/day followed by from transportation of chicken to slaughterhouses and from chicken incubation at 0.467±0.460 and 0.0003±0.0004 kg.C/kg.Thai native chicken/day. For raising systems, the traditional system emitted higher carbon (11.777±4.252 kg.C/kg.Thai native chicken/day) than the manufactural system (7.720±4.954 kg.C/kg.Thai native chicken/day). It can be concluded that most of carbon emission in energy use was from the transportation of both chicken feed and of chicken to slaughterhouses and small farm also emitted higher carbon than large farm ($P \leq 0.05$).

Keywords: Carbon emission, energy use, Thai native chicken, Nakhon Ratchasima province
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Introduction

A part of global warming problem is caused by livestock production which is a source of carbondioxide (CO_2), nitrogen oxides (NO_X) and methane (CH_4) that are released to the atmosphere (Thanee *et al.*, 2008). These greenhouse gases (GHG) cause the greenhouse effect which negatively affect the Earth's environment. Livestock farming contributes about 18% of world GHG emission, accounting for 9% of CO_2, 37-50% of CH_4 and 20-70% of nitrous oxide (N_2O) (OECD, 2000; IPCC, 2001; FAO, 2006; IPCC, 2007). The Intergovernmental Panel on Climate Change (IPCC, 1995) in England in 1995 concluded that global climate change has been mainly caused by GHG which most of them had been released from human activities. The Panel predicted that in 2100 the sea level will be raised up about 3 feet higher than the present level and the environment will be changed. Our world will face the serious environmental problems such as the decling of forests, the distribution and increase of pathogens, pollution, heat wave, drought, flood and storm. The IPCC (2007) suggested that GHG emission must be reduced considerably from their present levels in order to avoid climate change of a magnitude that will have serious negative consequences for the world communities (IPCC, 2007; Stern, 2006).

The demand for livestock products; largely meat, milk and eggs, is increasing globally. As a result, the world's livestock sector is also growing. Livestock production is growing faster than any other agricultural sub-sector and it is predicted that by 2020, livestock will produce more than half of the total global agricultural output in value terms (Delgado *et al.*, 1999); Upton, 2004). Livestock production in Thailand has been increased considerably especially chicken and ducks for their meat and eggs. Thai native chicken are one of preferred poultry for consumers and producers. However, data on carbon mass flow, carbon emission and carbon footprint in Thai native chicken production are still scanty (Vichairattanatragul, 2014).

Thus, the objectives of this rescaech were to in vestigate total carbon emission from the use of energy and to compare carbon emission between traditional and manufactural raising systems in Thai native ckicken production in Nakhon Ratchasima province, Thailand.

Materials and methods

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Study area

Nakhon Ratchasima or "Khorat" is the largest province, situates in the northeastern plateau in Thailand and has an area of around 20,494 square kilometres (7,913 sq mi). Nakhon Ratchasima province was selected as study area where many Thai native chicken have been raised based on the data of Nakhon Ratchasima provincial Livestovk Office (2013). The selected districts of Nakhon Ratchasima province were Mueang Nakhon Ratchasima, Kham Thale So, Sung Noen and Pak Thong Chai. The study areas are shown in Fig.1 and Fig. 2.

Site sampling and analytical methods

The numbers of farms and Thai native chicken in each district of selected provinces were calculated by Taro Yamane's formula (Yamane, 1973) as follow:

$$n = \frac{N}{1+Ne^2} \qquad (1)$$

Where, n = Sample size, N = Population size, e = The error of sampling

The calculation showed that sample sizes were 400 Thai native chicken farms and 400 Thai native chicken. All selected farm were divided into two groups; traditional raising system and manufactural raising system, depended on the number and the raising system of Thai native chicken production. The traditional system raised under 100 chicken per a farm while the manufactural had higher number of chicken (Personal communication). Statistical analyses were performed using SPSS versions 18, significance was based on $P \leq 0.05$ between traditional and manufactural systems.

Results and discussions

The total carbon emission from energy use

The survey, questionares and analyses of farms and slaughterhouses for energy use in chicken production in Nakhon Ratchasima province found that Thai native chicken farms had used much energy for raising chicken per kilogramme livestock animal per day (kg.C/kg.Thai native chicken/day). The total carbon emission (C-emission) from energy use of Thai native chicken production was 10.529± 4.834 kg.C/kg.Thai native chicken/day. Most energy was used for transportation of animal feed to farms and of Thai native chicken to slaughterhouses, and using electricity for incubation of small chicken and farm management. The results of each C-emission from the energy usage showed that C-emission form transportation of animal feed was the highest at 10.062±4.832 kg.C/kg.Thai native chicken/day followed by transportation of chicken to slaughterhouses and the energy used for incubation of small chicken at 0.467±0.460 and 0.0003±0.0004 kg.C/kg.Thai native chicken/day, respectively. The content and proportion of C-emission from the use of energy in Thai native chicken production in Nakhon Ratchasima province are shown in Table 1 and Fig. 3

The total carbon emission and carbon emission from transportation

In Thai native chicken production, total C-emission and C-emission from transportation of chicken feed to farms were 10.529±4.834 and 10.062±4.832 kg.C/kg.Thai native chicken/day, respectively. The relationship between these two sources of emission is shown in Fig. 4. The result found that total C-emission positively correlated with C-emission from transportation of chicken feed to farms ($P \leq 0.05$). The regression equation is also shown as follow:

$$y = 0.9951\,(x) - 0.4147 \qquad (R^2 = 0.991)$$

Y = Total C-emission of Thai native chicken
x = C-emission from transportation of chicken feed

The result coincide with the findings of Keeratiurai and Thanee (2000) who reported that carbon emission of layer chicken farms in Nakhon Ratchasima province was 36.65×10^{-3} kg.C/living weight/day. Keeratiurai and Thanee (2013) also found that carbon emission from broiler chicken production and young layer chicken production were 11.11×10^{-3} and 8.3×10^{-3} kg.C/living weight/day. They also discussed that most carbon emission is from

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the transportation of animal feed, transportation of animals to the markets and slaughterhouses. However, Poritosh *et al*. (2013) showed that carbon emission of chicken meat production in Japan was 18.45 kg.C/living weight/day. It is clear that most of livestock production, especially in South East Asia, emit the most carbon into the atmosphere.

The C-emission from Thai native chicken between traditional and manufactural raising systems

There were two raising systems in Thai native chicken in selected districts of Nakhon Ratchasima province. They were traditional and manufactural raising systems. In comparison of both systems, the result revealed that traditional raising system emitted higher carbon (11.777±4.252 kg.C/kg.Thai native chicken/day) than manufactural raising system (7.720± 4.954 kg.C/kg.Thai native chicken/day). There was significantly different ($P \leq 0.05$) between these two raising systems. The result is illustrated in Fig. 5 and the regression formula is as follow:

$$Y = 0.9949 (x) - 3.7684 \qquad (R^2 = 0.813)$$

Y = C-emission of traditional raising system
x = C-emission of manufactural raising system

This result can be concluded that in Thai native chicken production, the traditional raising system which had low number of chicken (lower than 100 chicken) emitted higher carbon than the manufactural raising system (higher than 100 chicken). This finding agree with the reports of Keeratiurai and Thanee (2010, 2013) and Keeratiurai et al. (2013) who found that most carbon in egg production, broiler meat production and layer farming in Nakhon Ratchasima province is from the use of energy for transportation of animal feed and transportation of animals to slaughterhouses. Moreover, smaller farms emit higher carbon because small farms normally use the same amount of oil, gas or petrol as big farms but the number of animals carried are fewer. Pelltier and Tyedmers (2010) and Tantipanatip (2014) also reported that most carbon emission from aquatic products and seafood in Indonesia and Thailand come from transportation especially in small farms. So the guidelines to reduce carbon emission from the use of energy for transportation of animal feed and transportation of animals to slaughterhouses should be considered and reduced.

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References

Blandford D., Gaasland I. and Vardal E. (2014). The trade-off between food production and greenhouse gas mitigation in Norwegian agriculture. Agriculture, Ecosystems and Environment 184: 59-66.

CNPP THAILAND. Country nuclear power profiles (2013); [on-line]. Available: http://www.pub.iaea.org/MTCD/Publications/PDF/CNPP2013CD/countryprofiles/Thailand/Figures/CNPP%20THAILAND%202013.pdf.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. and Courbois, C. (1999). Livestock to 2020: The next food revolution. Food, Agriculture and Environment Discussion Paper 28. Washington DC: International Food Policy Research Institute.

Food and Agricultural Organization (FAO), (2006). World Agriculture: Towards 2030/2050. Food and Agriculture Organization of the United Nations, Rome.

Food and Agricultural Organization (FAO), (2013). Tackling Climate Change Through Live-stock. FAO, Rome. [On-line]. Available: http://www.fao.org/docrep/018/i3437e/i3437e.pdf.

Gongruttananun N. (2011). Influence of red light on reproductive performance, eggshell ultrastructure and eye morphology in Thai-native hens. Poultry Science 90: 2855–2863.

Intergovernmental Panel on Climate Change (IPCC). (1995). Climate Change 1995, the Science of Climate Change. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Syndicate of the University of Cambridge, Cambridge, U.K. p. 572.

Intergovernmental Panel on Climate Change (IPCC). (2001). The Scientific Basis is the most comprehensive and up-to-date scientific assessment of past, present and future climate change. [Online]. Available: http://www.ipcc.ch/ipccreports/tar/wg1/pdf/WG1_TAR-FRONT.PDF.

Intergovernmental Panel on Climate Change (IPCC). (2007). Climate change-greenhouse gas emission [On-line]. Available: http//www.epa.gov/climatechange/emission/usinven-toryreport.html.

Keeratiurai P. and Thanee N. (2010). Carbon massflow and greenhouse gases emissions from egg production using life cycle assessment in Nakhon Ratchasima Province, Thailand. The 3rd Technology and Innovation for Sustainable Development International Conference, Nong Khai, Thailand.

Keeratiurai P. and Thanee N. (2013). Comparison of carbon equivalent emissions under uncertainty of energy using for industries of pig and broiler meat production. Science Series Data Report 5(5): 55-65.

Keeratiurai P., Thanee N. and Vichairattanatragul. (2013). Assessment of the carbon massflow from the layer farming with life cycle inventory. ARPN Journal of Agricultural and Biological Science 8(9): 673-682.

Maps of world. (2015). The administrative divisions of the Nakhon Ratchasima Province, Thailand. [Online]. Available: http://www.mapsofworld.com/thailand/provinces/nakhon-ratchasima-map.html. Accessed date: October 2015.

Journal of Agricultural Technology. Vol. 11(8):1973-1986
Available online http://www.ijat-aatsea.com
ISSN 1686-9141

Nakhonratchasima Provincial Livestock Office. (2013). [Online]. Available: http://pvlo-nak.dld.go.th/data/zone/zone57/chic57.jpg. Accessed date: October 2015.

Organisation for Economic Co-operation and Development [OECD]. (2000). Environmental indicators for agriculture methods and results. Executive Summary. Paris, France. 53p.

Poritosh RP., Orikasab T., Thammawonga M., Nakamuraa N., Xua O. and Shiinaa T. (2013). Life cycle of meats: An opportunity to abate the greenhouse gas emission from meat industry in Japan. Journal of Environmental Management 93: 218-224.

Pelletier, NL. And Tyedmer, PH. (2007). Feeding farmed salmon: Is organic better?. Aquaculture. 272: 399-416.

Steinfeld, H., Wassenaar, T. and Jutzi, S. (2006). Livestock production systems in developing countries: Status, drivers, trends. Revue Scientifique et Technique de l` Office International des Epizooties 25(2): 505-516.

Stern, N. (2006). The economics of climate change. Cambridge: Cambridge University Press. 712p.

Sullivan WG., Wicks EM. and Luxhoj JT. (2003). Engineering Economy. 12th ed. New Jersey: Pearson Education.

Tantipanatip, W. (2014). Carbon massflow of Pacific white shrimp, giant freshwater prawn and giant perch meat production from fishery farm to devrlop carbon footprints in Trang, Songkhla and Phatthalung provinces, Thailand. Ph.D. thesis. School of Biology, Institute of scicence, Suranaree University of Technology, Nakhon Ratchasima, Thailand.

Thanee, N., Dankitikul, W. and Keeratiurai, P. (2008). Comparison of carbon emission factors from ox and buffalo farms and slaughterhouses in meat production. In: Proceeding of the International Conference on Energy Security and Climate Change: Issues, Strategies, and Option; August 6-8, 2008; Sofitel Centara Grand, Bangkok, Thailand, pp. 52-53.

Thanee N., Dankitikul W. and Keeratiurai P. (2009a). The study of carbon massflow in ox, buffalo, and pig meat production from farms and slaughterhouses in Thailand. Thai Environmental Engineering 23(2): 37-51.

Thanee N., Dankitikul W. and Keeratiurai P. (2009b). Comparison of carbon emitted from ox, buffalo, pig, and chicken farms and slaughterhouses in meat production. Suranaree Journal of Science and Technology 16(2): 79-90.

TGO. (2011). Common data of carbon footprint analyzes. [on-line]. Available: http://conference.tgo.or.th/download/tgo_or_th/publication/CFP_Guideline_TH_Edition 3.pdf.

Upton, M. (2004). The role of livestock in economic development and poverty reduction. Food and Agriculture Organization: Pro-Poor Livestock Policy Initiative. PPLPI Working Paper No. 10.

Vichairattanatragul P. (2014). Carbon massflow of swine, goat, three breed-cross native chicken, puking duck and laying duck productions for carbon footprints development in Nakhon Ratchasima. Prachin Buri and Chon Buri provinces, Thailand. Ph.D. thesis. School of Biology, Institute of scicence, Suranaree University of Technology, Nakhon Ratchasima, Thailand.

Wattanachan S., Benjakul S. and Ledward D. A. (2004). Composition, color, and texture of Thai indigenous and broiler chicken muscles. Poultry Science 83:123–128.

Yamane T. (1973). Mathematics for Economists: An Elementary Survey. 2nd Ed. Prentice-Hall, New Delhi, India. p.714.

(Received xxxxxx, accepted xxxxxxx)

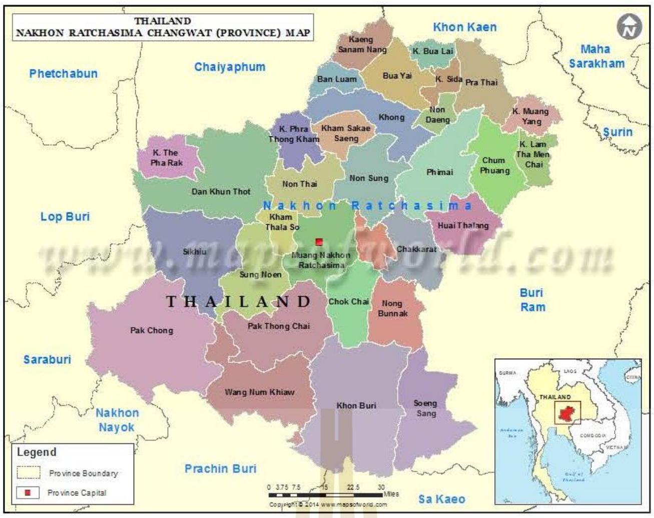

Fig. 1 The map of Nakhon Ratchasima province

Ref:http://www.mapsofworld.com/thailand/provinces/nakhonratcha
sima-map.html

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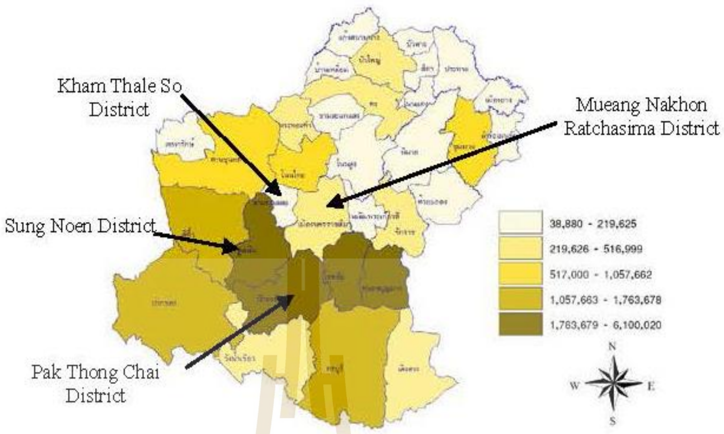

Fig. 2 Districts in Nakhon Ratchasima showing numbers of chicken Production

Ref: http://pvlo-nak.dld.go.th/data/zone/zone57/chic57.jpg

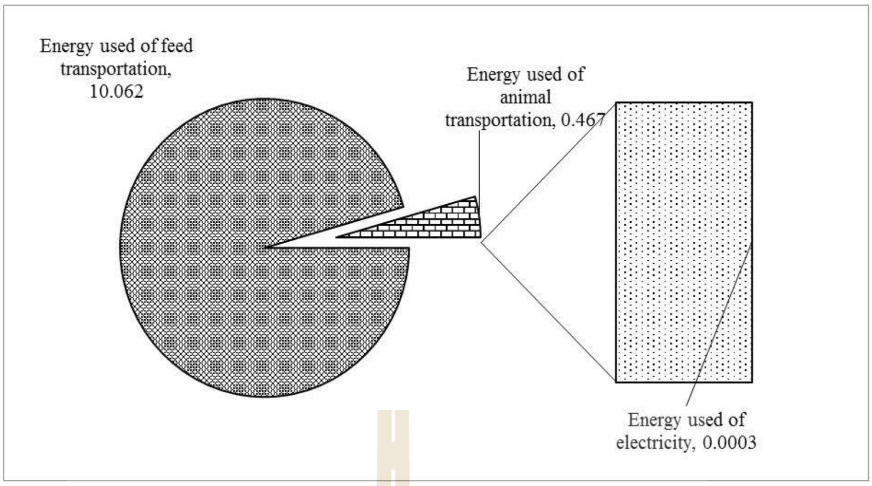

Fig. 3 The proportion of carbon emission from Thai native chicken production in NaKhon Ratchasima province

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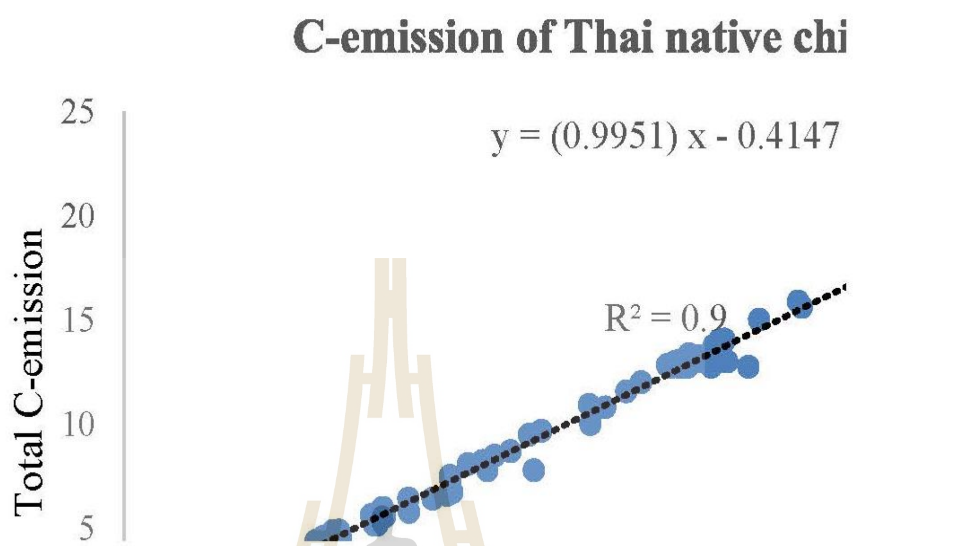

Fig. 4 The relationship between total C-emissionfrom energy use of Thai native chicken and C-emission from transportation of chicken feed at a confidence level of 95%.

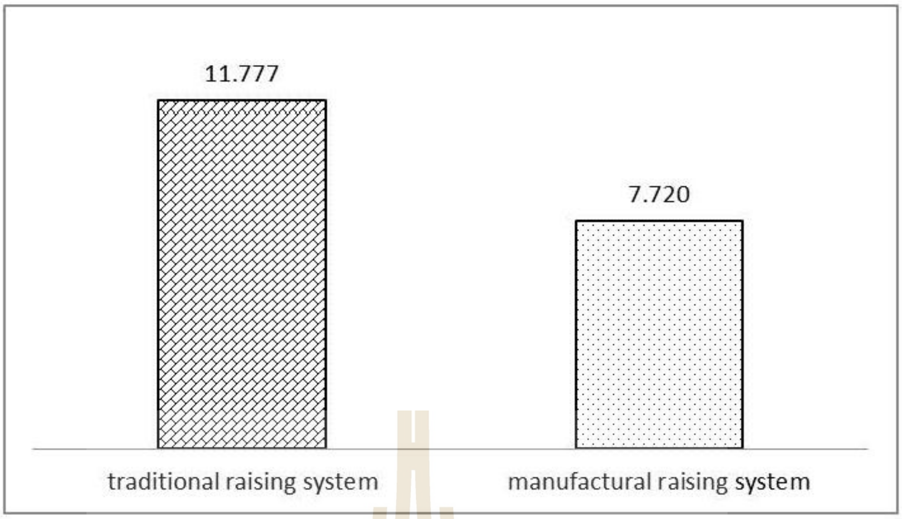

Fig. 5 The comparison of C-emission between traditional raising systemand manufactural raising system

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Table 1 The carbon emission from Thai native chicken production from farm management

Parameter	Thai native chicken (kg.C/kg.Thai native chicken/day)
Energy used of animal feed transportation	10.062±4.832
Energy used of animal transportation	0.467±0.460
Energy used of electricity	0.0003±0.0004

Table 2 The C-emission of Thai native chicken production between traditional raising system and manufactural raising system

Model	C-emission (kg.C/kg.Thai native chicken/day)
traditional raising system	11.777± 4.252
manufactural raising system	7.720± 4.954

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Table 3 Carbon emission scenarios from Thai native chicken production models follow the Payoff Matrix Principle

Alternative of model	Scenarios of C-emission (kg.C/kg.Thai native chicken/day)	
	C-emission from fuel	C-emission from electricity
traditional raising system	11.150	0.00040
manufactural raising system	7.614	0.00012

Table 4 Carbon emission scenarios for Thai native chicken production from the application of the Laplace's Rule.

Alternative of model	(C-emission from fuel + C-emission from electricity)
traditional raising system*	(11.150+0.00040)/2 = 5.575
manufactural raising system	(7.614+0.00012)/2= 3.807

Remark: *Selected livestock create maximum environmental problem

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Comparison on energy use in Thai native chicken and Nile tilapia productions in Nakhon Ratchasima province, Thailand

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Paiboon N., Thanee N., Vichiratanatrakul P., Tantipanatip W. and Kiratiurai P. (YEAR) Comparison on energy use in Thai native chicken and Nile tilapia productions in Nakhon Ratchasima province, Thailand. Journal of Agricultural Technology. x(x):xxx

Abstract

Thai native chicken and Nile tilapia productions usually have impacts on the environment such as soil, water and air quality. The purposes of this research were to evaluate total carbon emission and to compare carbon emission between Thai native chicken and Nile tilapia productions in Nakhon Ratchasima province, Thailand during January to June 2016. Survey and questionnaires were made and data were collected at 400 farms in districts of study area. The results showed that the highest carbon emission was from transportation of animal feed to farms (11.062±4.832 kg.C/kg.Thai native chicken/day and 6.520±4.954 kg.C/kg. Nile tilapia/day). The energy use for transportation of Thai native chicken to slaughterhouse was 0.767±0.460 kg.C/kg.Thai native chicken/day and of Nile tilapia to markets was 0.427±0.360 kg.C/kg. Nile tilapia/day. In addition, the energy uses for incubation of Thai native chicken and of Nile were 0.0003±0.0004 kg.C/kg.Thai native chicken/day and 0.0001±0.0003 kg.C/kg. Nile tilapia/day, respectively. Thai native chicken production also emitted higher total carbon than Nile tilapia production at 11.829±5.292 kg.C/kg.Thai native chicken/day and 6.947±5.314 kg.C/kg. Nile tilapia /day ($P \leq 0.05$). It can be concluded that most of carbon emission was from transportation of animals feed from factories/wholesales to farms followed by transportation of animals to slaughterhouse/markets and incubation of young animals and farms management in their farms.

Keywords: Carbon emission, energy use, Thai native chicken, Nile tilapia, Nakhon Ratchasima province

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Introduction

Greenhouse gases (GHG) cause the greenhouse effect which negatively affects the Earth's environment. Livestock farming contributes about 18% of world GHG emission, accounting for 9% of CO_2, 37-50% of CH_4 and 20-70% of nitrous oxide (N_2O) (OECD, 2000; IPCC, 2001; FAO, 2006; IPCC, 2007). The Intergovernmental Panel on Climate Change (IPCC, 1995) in England in 1995 concluded that global climate change has been mainly caused by GHG which most of them had been released from human activities. The Panel predicted that in 2100 the sea level will be raised up about 3 feet higher than the present level and the environment will be changed. Our world will face the serious environmental problems such as the decling of forests, the distribution and increase of pathogens, pollution, heat wave, drought, flood and storm. The IPCC (2007) suggested that GHG emission must be reduced considerably from their present levels in order to avoid climate change of a magnitude that will have serious negative consequences for the world communities (IPCC, 2007; Stern, 2006).

The demand for livestock and fishery products; largely meat, milk and eggs, is increasing globally. As a result, the world's livestock and fishery sector is also growing. Livestock and fishery production are growing faster than any other agricultural sub-sector and it is predicted that by 2020, livestock and fishery will produce more than half of the total global agricultural output in value terms (Delgado *et al.*, 1999); Upton, 2004). Livestock and fishery production in Thailand has been increased considerably especially chicken and ducks for their meat and eggs. Thai native chicken are one of preferred poultry for consumers and producers. However, data on carbon mass flow, carbon emission and carbon footprint in Thai native chicken production are still scanty (Vichairattanatragul, 2014).

The previous assessments of the Livestock Environment and Development (LEAD) initiative emphasized the livestock sector perspective and analyzed livestock-environment interactions from the perspective of a livestock production system. This updated assessment inverts this approach and starts from an environmental perspective. It attempts to provide an objective assessment of the many diverse livestock environment interactions. Economic, social and public health objectives are of course taken into account so as to reach realistic conclusions. This assessment then outlines a series of potential solutions that can effectively address the negative consequences of livestock and fishery productions (De Haan et al., 1997; Steinfeld et al., 1997; Tantipanatip et al., 2014).

Thus, the objectives of this rescaech were to in vestigate total carbon emission from the use of energy and to compare carbon emission between Thai

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native chicken and Nile tilapia production in Nakhon Ratchasima province, Thailand.

Materials and methods

Study area

Nakhon Ratchasima is the largest province in Thailand and it locates in the Northeastern. Nakhon Ratchasima province was selected as study area where many Thai native chicken and Nile tilapia have been raised based on the data of Nakhon Ratchasima provincial Livestovk Office and Department of Fisheries Nakhon Ratchasima (2013). The selected districts of Nakhon Ratchasima province were Mueang Nakhon Ratchasima and Pak Thong Chai. The study areas are shown in Fig.1 Fig. 2 and Table 1.

Site sampling and analytical methods

The numbers of farms, Thai native chicken and Nile tilapia in each district of selected province were calculated by Taro Yamane's formula (Yamane, 1973) as follow:

$$n = \frac{N}{1+Ne^2} \qquad (1)$$

Where, n = Sample size, N = Population size, e = The error of sampling

According to the calculation the number of Thai native chicken farm and Nile tilapia farms were each of 400, and Thai native chickens and Nile tilapia were each of 400 individuals. Statistical analyses were performed using SPSS versions 18, significance was based on $P \leq 0.05$ between Thai native chicken and Nile tilapia productions.

Results and discussions

The total carbon emission from energy use

The survey, questionares and analyses of farms and slaughterhouses for energy use in chicken and fish production in Nakhon Ratchasima province found that Thai native chicken and Nile tilapia farms had used much energy for raising chicken and fish. The total carbon emission (C-emission) from energy use of Thai native chicken and Nile tilapia productions were 11.829±5.292 kg.C/kg.Thai native chicken/day and 6.947±5.314 kg.C/kg.Nile tilapia/day. Most energy was used for transportation of animal feed to farms and of animal to slaughterhouses, and using electricity for incubation of animals and farm management. The results of each C-emission from the energy use showed that C-emission from transportation of animal feed was the highest at 11.062±4.832 kg.C/kg.Thai native chicken/day and 6.520±4.954 kg.C/kg.Nile tilapia/day followed by transportation of animal to slaughterhouses or markets and the energy use for incubation of animals and for farm mangement at 0.767±0.460 and 0.0003±0.0004 kg.C/kg.Thai native chicken/day for Thai native chicken and 0.427±0.360 and 0.0001±0.0003 kg.C/kg.Nile tilapia/day for Nile tilapia, respectively.

The content and proportion of C-emission from the use of energy in Thai native chicken and Nile tilapia productions in Nakhon Ratchasima province are shown in Table 2 and Fig. 3.

The total carbon emission from transportation

In Thai native chicken and Nile tilapia productions, total C-emission from transportation of chicken feed to farms were 11.829±5.292 kg.C/kg.Thai native chicken/day and 6.947±5.314 kg.C/kg.Nile tilapia/day. and 11.062±4.832 kg.C/kg.Thai native chicken/day and 6.520±4.954 kg.C/kg.Nile, respectively. The relationship between these two sources of emission is shown in Fig. 4 and Fig. 5.

Thai native chicken:

The result found that total C-emission positively correlated with C-emission from transportation of chicken feed to farms ($P \leq 0.05$). The regression equation is also shown as follow:

$$y = 0.9951\,(x) - 0.4147 \qquad (R^2 = 0.981)$$

Y = Total C-emission of Thai native chicken
x = C-emission from transportation of chicken feed

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Nile tilapia:

The result found that total C-emission positively correlated with C-emission from transportation of fishery feed to farms ($P \leq 0.05$). The regression equation is also shown as follow:

$$y = 0.9781\,(x) - 0.3127 \qquad (R^2 = 0.892)$$

Y = Total C-emission of Nile tilapia
x = C-emission from transportation of fishery feed

The result coincide with the findings of Keeratiurai and Thanee (2000) who reported that carbon emission of layer chicken farms in Nakhon Ratchasima province was 36.65 x 10^{-3} kg.C/living weight/day. Keeratiurai and Thanee (2013) also found that carbon emission from broiler chicken production and young layer chicken productions were 11.11 x 10^{-3} and 8.3 x 10^{-3} kg.C/living weight/day. They also discussed that most carbon emission was from the transportation of animal feed, transportation of animals to the markets and slaughterhouses. However, Poritosh *et al.* (2013) showed that carbon emission of chicken meat production in Japan was 18.45 kg.C/living weight/day. It is clear that most of livestock production, especially in South East Asia, emit the most carbon into the atmosphere.

The C-emission between Thai native chicken and Nile tilapia productions

The two different groups of animals were selected in Nakhon Ratchasima province. They were Thai native chicken and Nile tilapia. In comparison of both animals, the result revealed that Thai native chicken emitted higher carbon (11.829±5.292 kg.C/kg.Thai native chicken/day) than Nile tilapia (6.947±5.314 kg.C/kg.Nile tilapia/day). There was significantly different ($P \leq 0.05$) between these two groups of animals. The results are illustrated in Fig. 6 and the regression formula is as follow:

$$Y = 0.9829\,(x) - 3.8751 \qquad (R^2 = 0.612)$$

Y = C-emission of Thai native chicken
x = C-emission of Nile tilapia

This results can be concluded that in both animals, Thai native chicken emitted higher carbon than Nile tilapia. This finding agree with the reports of Keeratiurai and Thanee (2010, 2013) and Keeratiurai et al. (2013) who found that most carbon in egg production, broiler meat production and layer farming in Nakhon Ratchasima province was from the use of energy for transportation of animal feed and transportation of animals to slaughterhouses. Moreover, smaller farms emit higher carbon because small farms normally use the same amount of oil, gas or petrol as big farms but the number of animals carried are fewer. Pelltier and Tyedmers (2010) and Tantipanatip (2014) also reported that most carbon emission from aquatic products and seafood in Indonesia and Thailand came from transportation especially in small farms. So the guidelines to reduce carbon emission from the use of energy for transportation of animal feed and transportation of animals to slaughterhouses should be considered and reduced.

Acknowledgement

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References

Blandford D., Gaasland I. and Vardal E. (2014). The trade-off between food production and greenhouse gas mitigation in Norwegian agriculture. Agriculture, Ecosystems and Environment 184: 59-66.

CNPP THAILAND. Country nuclear power profiles (2013); [on-line]. Available: http://www.pub.iaea.org/MTCD/Publications/PDF/CNPP2013CD/countryprofiles/Thailand/Figures/CNPP%20THAILAND%202013.pdf.

De Haan C., Steinfeld H. and Blackburn, H. (1997). Livestock and the environment finding a balance. E.U. Development Policy Sustainable Development and Natural Resources. U.K.: WREN Media Eye.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. and Courbois, C. (1999). Livestock to 2020: The next food revolution. Food, Agriculture and Environment Discussion Paper 28. Washington DC: International Food Policy Research Institute.

Food and Agricultural Organization (FAO), (2006). World Agriculture: Towards 2030/2050. Food and Agriculture Organization of the United Nations, Rome.

Food and Agricultural Organization (FAO), (2013). Tackling Climate Change Through Livestock. FAO, Rome. [On-line]. Available: http://www.fao.org/docrep/018/i3437e/i3437e.pdf.

Gongruttananun N. (2011). Influence of red light on reproductive performance, eggshell ultrastructure and eye morphology in Thai-native hens. Poultry Science 90: 2855–2863.

Intergovernmental Panel on Climate Change (IPCC). (1995). Climate Change 1995, the Science of Climate Change. Contribution of Working Group I to the Second Assessment Report

Journal of Agricultural Technology 2016 Vol. 12(7.1):1607-1617
Available online http://www.ijat-aatsea.com
ISSN 1686-9141

of the Intergovernmental Panel on Climate Change. Syndicate of the University of Cambridge, Cambridge, U.K. p. 572.

Intergovernmental Panel on Climate Change (IPCC). (2001). The Scientific Basis is the most comprehensive and up-to-date scientific assessment of past, present and future climate change. [Online]. Available: http://www.ipcc.ch/ipccreports/tar/wg1/pdf/WG1_TAR-FRONT.PDF.

Intergovernmental Panel on Climate Change (IPCC). (2007). Climate change-greenhouse gas emission [On-line]. Available: http//www.epa.gov/climatechange/emission/usinven-toryreport.html.

Keeratiurai P. and Thanee N. (2010). Carbon massflow and greenhouse gases emissions from egg production using life cycle assessment in Nakhon Ratchasima Province, Thailand. The 3rd Technology and Innovation for Sustainable Development International Conference, Nong Khai, Thailand.

Keeratiurai P. and Thanee N. (2013). Comparison of carbon equivalent emissions under uncertainty of energy using for industries of pig and broiler meat production. Science Series Data Report 5(5): 55-65.

Keeratiurai P., Thanee N. and Vichairattanatragul. (2013). Assessment of the carbon massflow from the layer farming with life cycle inventory. ARPN Journal of Agricultural and Biological Science 8(9): 673-682.

Maps of world. (2015). The administrative divisions of the Nakhon Ratchasima Province, Thailand. [Online]. Available: http://www.mapsofworld.com/thailand/provinces/nakhon-ratchasima-map.html. Accessed date: October 2015.

Nakhonratchasima Provincial Livestock Office. (2013). [Online]. Available: http://pvlo-nak.dld.go.th/data/zone/zone57/chic57.jpg. Accessed date: October 2015.

Organisation for Economic Co-operation and Development [OECD]. (2000). Environmental indicators for agriculture methods and results. Executive Summary. Paris, France. 53p.

Poritosh RP., Orikasab T., Thammawonga M., Nakamuraa N., Xua O. and Shiinaa T. (2013). Life cycle of meats: An opportunity to abate the greenhouse gas emission from meat industry in Japan. Journal of Environmental Management 93: 218-224.

Pelletier, NL. And Tyedmer, PH. (2007). Feeding farmed salmon: Is organic better?. Aquaculture. 272: 399-416.

Steinfeld, H., Wassenaar, T. and Jutzi, S. (2006). Livestock production systems in developing countries: Status, drivers, trends. Revue Scientifique et Technique de l` Office International des Epizooties 25(2): 505-516.

Steinfeld, H., de Haan, C. and Blackburn, H. (1997). Livestock-Environment Interactions Issues and Options. E.U. Development Policy Sustainable Development and Natural Resources, WREN Media Eye, UK.

Stern, N. (2006). The economics of climate change. Cambridge: Cambridge University Press. 712p.

Sullivan WG., Wicks EM. and Luxhoj JT. (2003). Engineering Economy. 12th ed. New Jersey: Pearson Education.

Tantipanatip, W. (2014). Carbon massflow of Pacific white shrimp, giant freshwater prawn and giant perch meat production from fishery farm to devrlop carbon footprints in Trang, Songkhla and Phatthalung provinces, Thailand. Ph.D. thesis. School of Biology, Institute of scicence, Suranaree University of Technology, Nakhon Ratchasima, Thailand.

Tantipanatip, W., Jitpukdee, S., Keeratiurai, P., Tantikamton, K. and Thanee, N.

(2014). Life cycle assessment of Pacific white shrimp (Penaeus vannamei) farming system in Trang province, Thailand. Advanced Materials Research. 1030-1032: 679-682.

Thanee, N., Dankitikul, W. and Keeratiurai, P. (2008). Comparison of carbon emission factors from ox and buffalo farms and slaughterhouses in meat production. In: Proceeding of the International Conference on Energy Security and Climate Change: Issues, Strategies, and Option; August 6-8, 2008; Sofitel Centara Grand, Bangkok, Thailand, pp. 52-53.

Thanee N., Dankitikul W. and Keeratiurai P. (2009a). The study of carbon massflow in ox, buffalo, and pig meat production from farms and slaughterhouses in Thailand. Thai Environmental Engineering 23(2): 37-51.

Thanee N., Dankitikul W. and Keeratiurai P. (2009b). Comparison of carbon emitted from ox, buffalo, pig, and chicken farms and slaughterhouses in meat production. Suranaree Journal of Science and Technology 16(2): 79-90.

TGO. (2011). Common data of carbon footprint analyzes. [on-line]. Available: http://conference.tgo.or.th/download/tgo_or_th/publication/CFP_Guideline_TH_Edition 3.pdf.

Upton, M. (2004). The role of livestock in economic development and poverty reduction. Food and Agriculture Organization: Pro-Poor Livestock Policy Initiative. PPLPI Working Paper No. 10.

Vichairattanatragul P. (2014). Carbon massflow of swine, goat, three breed-cross native chicken, puking duck and laying duck productions for carbon footprints development in Nakhon Ratchasima. Prachin Buri and Chon Buri provinces, Thailand. Ph.D. thesis. School of Biology, Institute of scicence, Suranaree University of Technology, Nakhon Ratchasima, Thailand.

Wattanachan S., Benjakul S. and Ledward D. A. (2004). Composition, color, and texture of Thai indigenous and broiler chicken muscles. Poultry Science 83:123–128.

Yamane T. (1973). Mathematics for Economists: An Elementary Survey. 2nd Ed. Prentice-Hall, New Delhi, India. p.714.

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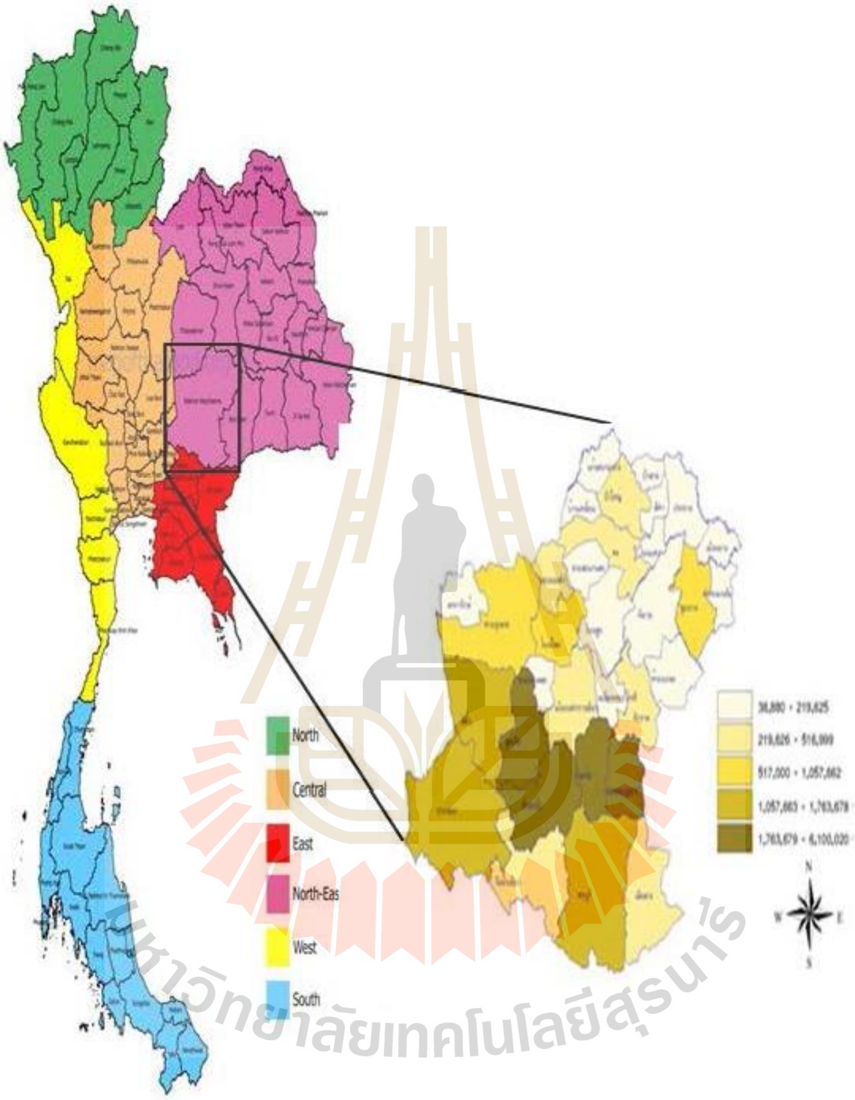

Fig. 1 The map of Nakhon Ratchasima province.

Ref:http://www.mapsofworld.com/thailand/provinces/nakhonratchasima-map.html

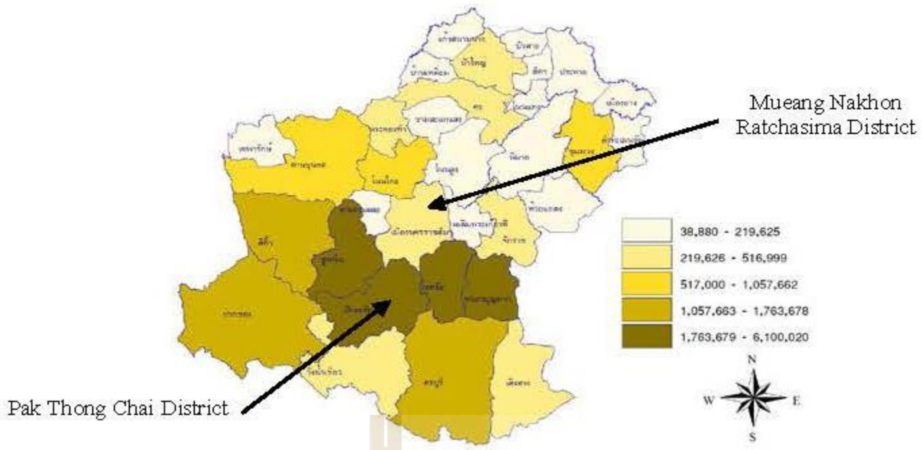

Fig. 2 Districts in Nakhon Ratchasima showing numbers of chicken productions.

Ref: http://pvlo-nak.dld.go.th/data/zone/zone57/chic57.jpg

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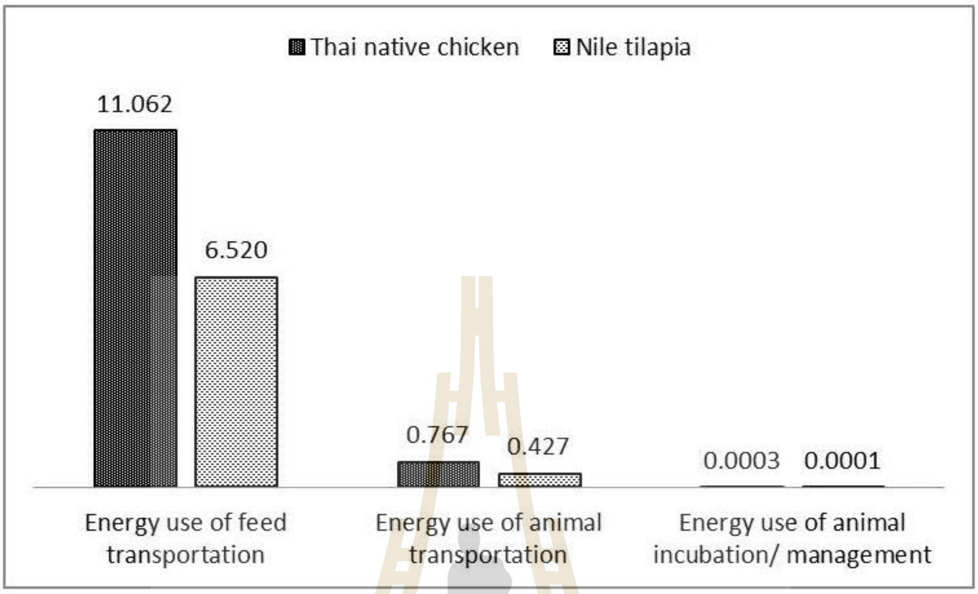

Fig. 3 The proportion of carbon emission from Thai native chicken and Nile tilapia productions in Nakhon Ratchasima province.

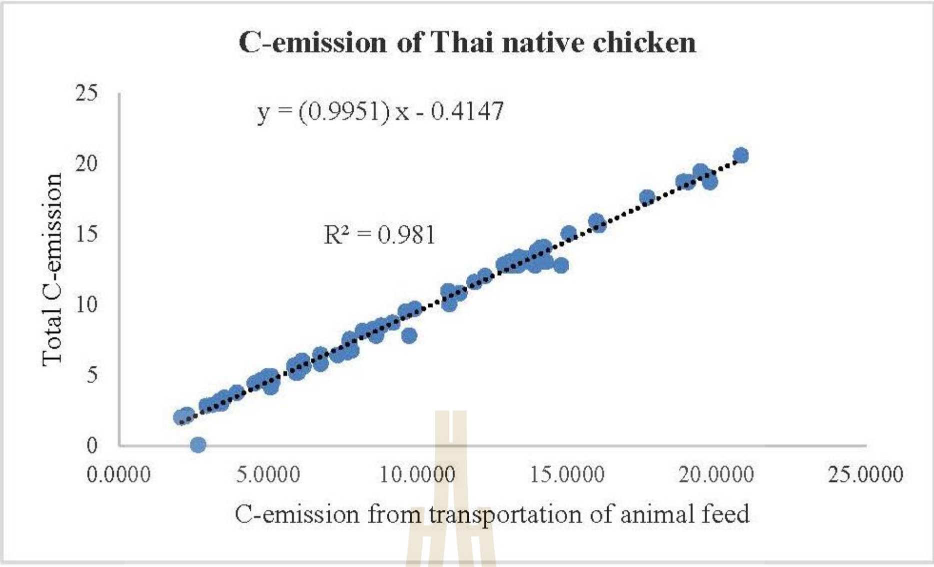

Fig. 4 The relationship between C-emission from energy use of Thai native chicken and C-emission from transportation of chicken feed at a confidence level of 95%.

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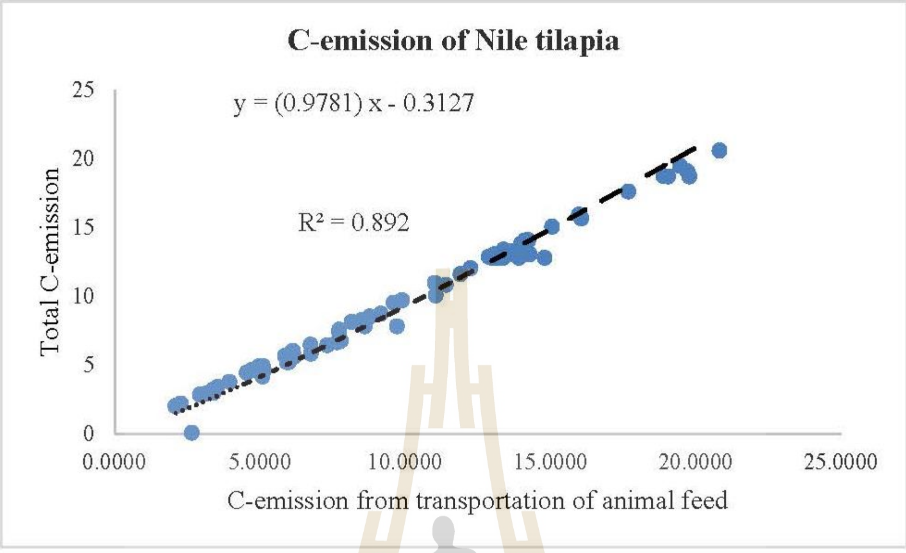

Fig. 5 The relationship between C-emission from energy use of Nile tilapia and C-emission from transportation of fishery feed at a confidence level of 95%.

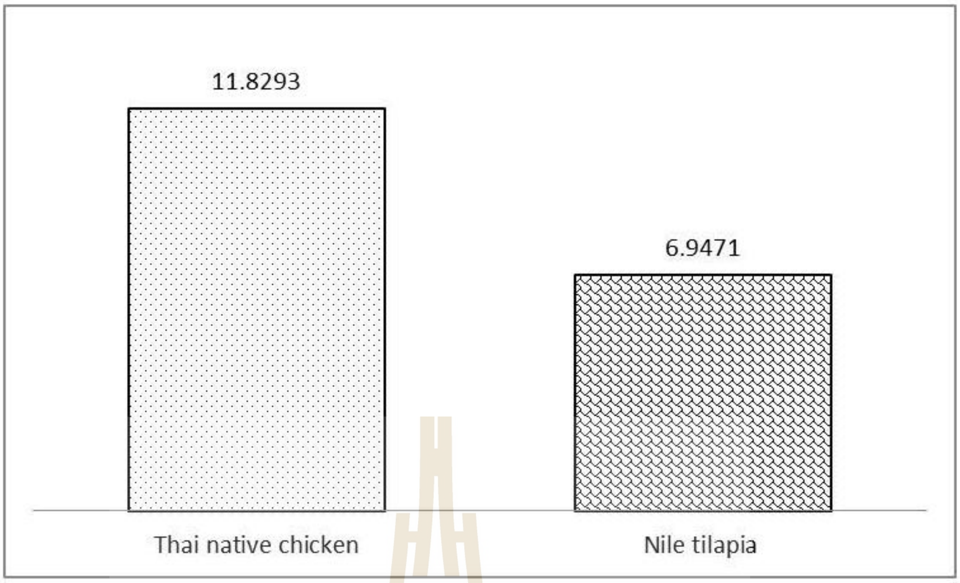

Fig. 6 The comparison of tota C-emission from energy use between Thai native chicken and Nile tilapia.

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Table 1 The number of Nile tilapia farms in Mueang Nakhon Ratchasima and Pak Thong Chai districts in 2015.

Districts	The size of farm				Subsistence farming	Commercial farming
	<1 rais and feed	1 - 5 rais and feed	>5 rais and feed	Sum		
Mueang Nakhon Ratchasima	223	655	62	940	808	132
Pak Thong Chai	402	656	8	1,066	1,043	23
Total				2,006	1,851	155

Source: Fishery Office in Nakhon Ratchasima, (2015).

Table 2 The carbon emission from Thai native chicken and Nile tilapia productions from farm management

Parameter	Thai native chicken (kg.C/kg.Thai native chicken/day)	Nile tilapia (kg.C/kg. Nile tilapia /day)
Energy use of animal feed transportation	11.062±4.832	6.520±4.954
Energy use of animal transportation	0.767±0.460	0.427±0.360
Energy use of animal incubation/ management	0.0003±0.0004	0.0001±0.0003

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Natthakittiya Paiboon, Nathawut Thanee, Panisara Vichiratanatrakul, Watcharaporn Tantipanatip, and Prayong Kiratiurai. (2016). Comparison on energy use in Thainative chicken and Nile Tilapia productions in Nakhon Ratchasima province, Thailand. **Journal of Agricultural Technology**. Vol. 12(7.1): 1605-1615.