CARBON MASSFLOW OF SWINE, GOAT, THREE BREED-CROSS NATIVE CHICKEN, PEKIN DUCK AND LAYING DUCK PRODUCTIONS FOR CARBON FOOTPRINTS DEVELOPMENT IN NAKHON RATCHASIMA, PRACHIN BURI AND CHON BURI PROVINCES, THAILAND

Panisara Vichairattanatragul

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การถ่ายเทมวลคาร์บอนของการผลิตสุกร แพะ ไก่ลูกผสมสามสาย เป็ดเนื้อ และเป็ดไข่เพื่อพัฒนาค่าคาร์บอนฟุตพรินท์ในจังหวัดนครราชสีมา จังหวัดปราจีนบุรี และจังหวัดชลบุรี ประเทศไทย

นายปาณิสรา วิชัยรัตนตระกูล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาชีววิทยาสิ่งแวดล้อม
มหาวิทยาลัยเทคโนโลยีสุรนารี
ปีการศึกษา 2557

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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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ปาณิสรา วิชัยรัตนตระกูล : การถ่ายเทมวลคาร์บอนของการผลิตสุกร แพะ ไก่ลูกผสมสามสาย เป็ดเนื้อ และเป็ดไข่เพื่อพัฒนาค่าคาร์บอนฟุตพรินท์ในจังหวัดนครราชสีมา จังหวัดปราจีนบุรี และจังหวัดชลบุรี ประเทศไทย (CARBON MASSFLOW OF SWINE, GOAT, THREE BREED-CROSS NATIVE CHICKEN, PEKIN DUCK AND LAYING DUCK PRODUCTIONS FOR CARBON FOOTPRINTS DEVELOPMENT IN NAKHON RATCHASIMA, PRACHIN BURI AND CHON BURI PROVINCES, THAILAND) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.ณัฐวุฒิ ธานี, 186 หน้า.

สภาวะเรือนกระจกก่อให้เกิดปัญหาโลกร้อนซึ่งเป็นปัญหาทางสิ่งแวดล้อม ปัจจัยสำคัญที่ก่อให้เกิดปัญหานี้คือ แก๊สคาร์บอนไดออกไซด์ ไนโตรเจนออกไซด์ และมีเทน การทำปศุสัตว์ โดยเฉพาะการใช้พลังงานสำหรับการเลี้ยง เพื่อการผลิตเนื้อและไข่ เป็นสาเหตุหนึ่งของการเพิ่มปริมาณแก๊สเหล่านี้ในบรรยากาศ การศึกษาการถ่ายเท และการปลดปล่อยคาร์บอนจากการทำฟาร์มในงานวิจัยนี้ได้เลือกศึกษาสุกร แพะ ไก่ลูกผสมสามสาย เป็ดเนื้อ และเป็ดไข่ เพื่อศึกษาอัตราการถ่ายเทมวลคาร์บอนจากพืชอาหารสัตว์ไปสู่สัตว์ทั้งห้าชนิดโดยการกิน และศึกษาอัตราการปลดปล่อยปริมาณคาร์บอนจากการเลี้ยงสัตว์ และการใช้พลังงานไฟฟ้า น้ำมันเชื้อเพลิง และแก๊สปิโตรเลียมเหลว ที่มีส่วนสำคัญในกระบวนการผลิตเนื้อ และไข่ จากการทำฟาร์มปศุสัตว์ในจังหวัดนครราชสีมา ปราจีนบุรี และชลบุรี ในระหว่างเดือนตุลาคม พ.ศ. 2554 ถึงเดือนกันยายน พ.ศ. 2555 ในการศึกษาครั้งนี้ได้สำรวจและสอบถามข้อมูลการเลี้ยงสัตว์จากเกษตรกรเจ้าของฟาร์ม และโรงฆ่าสัตว์ในจังหวัดนครราชสีมา 32 อำเภอและ 6 กิ่งอำเภอ (จะรวมเรียกเป็น 32 อำเภอ) จังหวัดปราจีนบุรี 7 อำเภอ จังหวัดชลบุรี 11 อำเภอ พร้อมทั้งนำตัวอย่างเนื้อสัตว์ ไข่ อาหารสัตว์ และมูลสัตว์ มาวิเคราะห์หาปริมาณการถ่ายเทมวลคาร์บอนจากการผลิตสัตว์ทั้งห้าชนิดในห้องปฏิบัติการ ผลการศึกษาการถ่ายเทมวลคาร์บอนจากอาหารสัตว์ไปสู่ตัวสัตว์โดยผ่านขบวนการกินอาหารโดยเรียงลำดับจากมากที่สุดไปหาน้อยที่สุด พบว่าแพะกินอาหารปริมาณมากที่สุด รองลงมาได้แก่ สุกร เป็ดไข่ เป็ดเนื้อ และไก่ลูกผสมสามสาย มีค่า 1.130±1.68 0.942±0.04 0.143±0.57 0.114±0.58 และ 0.047±0.48 กิโลกรัมคาร์บอนต่อกิโลกรัมน้ำหนักสัตว์ต่อวัน ตามลำดับ ความสามารถของสัตว์ในการตรึงคาร์บอนมาสะสมไว้ในตัวสัตว์ เรียงลำดับจากมากที่สุดไปหาน้อยสุดคือ แพะ สุกร เป็ดไข่ เป็ดเนื้อ และไก่ลูกผสมสามสาย เท่ากับ 0.713±1.14 0.641±0.63 0.094±1.18 0.086±0.81 และ 0.031±0.49กิโลกรัมคาร์บอนต่อกิโลกรัมน้ำหนักสัตว์ต่อวัน ตามลำดับ อัตราการปลดปล่อยคาร์บอนเรียงลำดับจากมากที่สุดไปหาน้อยที่สุด คือ แพะ สุกร เป็ดไข่ เป็ดเนื้อ และไก่ลูกผสมสามสาย เท่ากับ 0.383±1.46 0.275±0.58 0.046±1.37 0.035±0.79 และ 0.016±0.63 กิโลกรัมคาร์บอนต่อกิโลกรัมน้ำหนักสัตว์ต่อวัน ตามลำดับ นอกจากนี้การปลดปล่อยคาร์บอนจากการใช้

พลังภายในฟาร์มและโรงฆ่าสัตว์ เรียงลำดับจากมากที่สุดไปหาน้อยที่สุดคือจากฟาร์มและโรงฆ่าสัตว์ของสุกร แพะ เป็ดเนื้อ เป็ดไข่ และไก่ลูกผสมสามสาย เท่ากับ 3.170±0.85 2.311±0.04 0.134±0.15 0.085±0.07 และ 0.070±0.06 กิโลกรัมคาร์บอนต่อกิโลกรัมน้ำหนักสัตว์ต่อวัน ตามลำดับ การเปรียบเทียบผลจากประสิทธิภาพการตรึงคาร์บอนพบว่า สุกรมีประสิทธิภาพการตรึงปริมาณคาร์บอนจากอาหารสำเร็จรูปที่ใช้เลี้ยงสุกรมาสะสมไว้ในร่างกายได้มาก สูงที่สุดคือ ร้อยละ 68.79 รองลงมาคือ เป็ดเนื้อ ร้อยละ 67.11 เป็ดไข่ ร้อยละ 65.74 ไก่ลูกผสมสามสาย ร้อยละ 64.85 และต่ำที่สุดคือแพะ ร้อยละ 63.09 สามารถสรุปได้ว่าในแต่ละวันสุกร 1 ตัว มีการปลดปล่อยคาร์บอนออกจากร่างกายน้อยกว่าสัตว์อื่นเมื่อเทียบจากปริมาณคาร์บอนที่กินเข้าไปเท่ากัน ดังนั้นสุกรจึงมีส่วนทำให้เกิดปัญหาทางสิ่งแวดล้อมในเรื่องของการปลดปล่อยคาร์บอนน้อยที่สุดในกลุ่มสัตว์ที่ใช้ศึกษา

สาขาวิชาชีววิทยา	ลายมือชื่อนักศึกษา__________________________
ปีการศึกษา 2557	ลายมือชื่ออาจารย์ที่ปรึกษา____________________
	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม ________________

PANISARA VICHAIRATTANATRAGUL : CARBON MASSFLOW OF SWINE, GOAT, THREE BREED-CROSS NATIVE CHICKEN, PEKIN DUCK AND LAYING DUCK PRODUCTIONS FOR CARBON FOOTPRINTS DEVELOPMENT IN NAKHON RATCHASIMA, PRACHIN BURI AND CHON BURI PROVINCES, THAILAND. THESIS ADVISOR : ASST. PROF. NATHAWUT THANEE, Ph.D. 186 PP.

CARBON MASSFLOW/CARBON EMISSION/CARBON FOOTPRINT/ LIVESTOCK PRODUCTION/THAILAND

One of the environmental threats that our planet faces today is the greenhouse effect. The important greenhouse gases including carbon dioxide (CO_2), nitrogen oxide (NO_x) and methane (CH_4) which cause global warming. Livestock production especially the use of energy in the process is a cause which releases these gases to the atmosphere. The main objectives of these studies were to investigate the rate of carbon massflow from animal feed to 5 livestock: swine, goat, three breed-cross native chicken, pekin duck and laying duck, and to study carbon emission from energy use, petroleum oil and liquefied petroleum gas (LPG) in meat and egg productions. The field research was conducted in 26 districts and 6 sub-communes (called 32 districts) in Nakhon Ratchasima, 7 districts in Prachin Buri and 11 districts in Chon Buri provinces during October, 2011 to September, 2012. Samples of grass and feed used for feeding, meat, eggs and the faeces produced were collected and transferred to the laboratory for analyses. The results found that the carbon massflow from feed to animals ranking from the highest to the lowest of carbon input were goats, swine, laying ducks, pekin ducks and three breed-cross native chicken at 1.130±1.68, 0.942±0.04, 0.143±0.57, 0.114±0.58 and 0.047±0.48 kg.C/kg.animal/day, respectively. In addition, the ranking of carbon fixation in animal bodies from the highest to the lowest were goats, swine, laying ducks, pekin ducks and three breed-cross native chicken at 0.713±1.14, 0.641±0.63, 0.094±1.18, 0.086±0.81 and 0.031±0.49 kg.C/kg.animal/day, respectively. Moreover, the ranking of carbon emission from studied livestock from the highest to the lowest were goats, swine, laying ducks, pekin ducks and three breed-cross native chicken at 0.383±1.46, 0.275±0.58, 0.046±1.37, 0.035±0.79 and 0.016±0.63 kg.C/kg.animal/day, respectively. Furthermore, the orders of carbon emission form energy use in farms and slaughterhouses from the highest to the lowest were from swine, goats, pekin ducks, laying ducks and three breed-cross native chicken, at 3.170±0.85, 2.311±0.04, 0.134±0.15, 0.085±0.07 and 0.070±0.06 kg.C/kg.animal/day, respectively. In addition, swine had the highest fixation efficacy from animal feed to animal at 68.79% followed by laying ducks (67.11%), pekin ducks (65.74%), three breed-cross native chicken (64.85%) and goats had the lowest at 63.09%. It can be concluded that the swine emitted the least carbon in each day compared with these studied livestock that consumed the same amount of carbon. Consequently, the carbon emission from pork production created the lowest environmental problems compared to the other studied livestock.

School of Biology — Student's Signature________________

Academic Year 2014 — Advisor's Signature________________

Co-advisor's Signature______________

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Panisara Vichairattanatragul

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LIST OF ABBREVIATIONS

C	=	Carbon content
C_{input} or C-input	=	Average carbon content in animal feed and average carbon input in from energy consumption
$C_{fixation}$ or C-fixation	=	Average carbon content which was fixed in livestock animal body
$C_{emission}$ or C-emission	=	Average carbon emission from energy consumption of livestock meat and egg productions
$C_{emitted}$ or C-emitted	=	Average carbon emitted in the form of livestock animal faeces including CO_2 and CH_4 from faeces, digestion and respiration
C_{output} or C-output	=	Average carbon content was in the form of livestock animal faeces
FCR	=	Feed conversion ratio is a measure of the amount of feed consume per unit of bodyweight gain or carcass weight gain
GWP	=	Global warming potential
GHG	=	Greenhouse gas
CO_2	=	Carbon dioxide

LIST OF ABBREVIATIONS (Continued)

CH_4	=	Methane
N_2O	=	Nitrous oxide
NO_X	=	Nitrogen oxide
LPG	=	Liquefied petroleum gas
kWh	=	Kilowatt-hour
Kg	=	Kilogramme
KJ	=	Kilojoule
TCN	=	Three breed-cross native chicken
^{o}C	=	Degree Celsius

CHAPTER I

INTRODUCTION

1.1 The subject relevance

Livestock refers to any breed or population of animal used for commercial purposes. Some people may use the livestock as domestic animals (Thornton, Van de Steeg, Notenbaert and Herrero, 2009). Livestock also means animals kept for husbandry or for family food including, but not limited to, all of the following. Large livestock means horses, mules, burros, asses, cattle, sheep, goats, llamas, swine and other similarly sized farm, hoofed domesticated animals, excluding dogs, cats and ferrets. Small livestock means chickens, turkeys, ducks, geese, pigeons, pheasants, rabbits and other similarly sized animals, excluding dogs, cats and ferret (Department of Livestock Development, 2009).

Livestock animals meet a variety of food needs for people. They are important sources of nutritional protein in the form of meat, milk, eggs, and processed products. More than half of all protein consumed is sourced from livestock and fish, which are more complete sources of essential amino acids than plants (Lauhajinda, 2006). Livestock is part of global ecological and food production systems and a key commodity for people. Their importance in the provision of food, incomes, employment, nutrients and risk insurance to mankind is widely recognized. Livestock systems are changing rapidly in response to a variety of drivers. Globally, human population is expected to increase from around 7.5 billion today to 8.2 billion by

2050. Rapid urbanization and increases in income are expected to continue in developing countries, and as a consequence the global demand for livestock products will continue to increase significantly in the coming decades (Herrmann, Anyamba, and Tucker, 2005; Herrero, Thornton, Gerber and Reid, 2009). The Food and Agriculture Organization of the United Nation (FAO) reports that livestock production is one of the major causes of the world's most pressing environmental problems, including global warming, land degradation, air and water pollution and loss of biodiversity. This report estimates that livestock are responsible for 18% of greenhouse gas (GHG) emissions, a bigger share than transport. However, the livestock sector's potential contribution to solving environmental problems is samely large and major improvements could be achieved at reasonable cost (FAO, 2006).

Livestock 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. How can livestock producers take advantage of the increasing demand for livestock products, where this is feasible, and how can the livestock assets of the poor be protected in the face of changing and increasingly variable climates (Thornton, Van de Steeg, Notenbaert and Herrero, 2009). Livestock systems have often been the subject of substantial public debate because in the process of providing social benefits some systems 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 the many sectors that need to grow to satisfy human demands, more trade-offs in the use of natural resources can be expected (Herrero, Thornton, Gerber and Reid, 2009; Mc Dermott, Staal, Freeman, Herrero and Van de Steeg, 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, Wassenaar and Jutzi, 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). These are the major domestic animal species, such as *Bos taurus* (cattle), *Gallus domesticus* (chicken), *Sus domesticus* (swine), *Capra hircus* (goats), *Ovis sries* (sheep) and *Anus domesticus* (duck).

In Thailand, some researchers have studied livestock GHG emission from livestock to environment. Some researchers reported GHG emission from pork production in Nakhon Ratchasima province, but none from meat goat, meat three breed-cross native chicken, meat pekin duck and laying duck productions (Thanee, Dankitikul and Keeratiurai, 2008). However, one of the environmental threats that our planet faces today is the greenhouse effect. A part of global warming problem is caused by livestock production which is a source of carbon dioxide (CO_2) and methane (CH_4) releases to the atmosphere. Swine, goats, three breed-cross native chicken, pekin duck and laying ducks are energy-users that are raised for their meat and eggs and all activities produce emissions of both CO_2 and CH_4. In 1995, Intergovernmental Panel on Climate Change (IPCC) in England concluded that the global climate change is mainly caused by GHG which were released from human activities. The prevention or solution of these problems is the way that people have to reduce activities that cause the increasing of the GHG.

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 production (De Haan, Steinfeld and Blackburn, 1997; Steinfeld, De Haan and Blackburn, 1997).

Livestock maintenance has a substantial impact on the world's water, land and biodiversity resources and thus contributes significantly to climate change. Directly and indirectly, grazing and 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 (De Haan, Steinfeld and Blackburn, 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, Jonas, Erb and Haberl, 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, Wilson, Perez-Garcia, Bowyer and Meil, 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, Lippke, Comnick and Manriquez, 2005).

Carbon is an important element of plants, animals and humans. Carbon dioxide and methane from human activities are the most important GHG contributing to global climate change. Goats are small ruminants while swine, three breed-cross native chicken, pekin duck and laying ducks are energy users that are raised for meat, eggs and produce emissions of both CO_2 and CH_4. The carbon budget of swine, goats, three breed-cross native chicken, pekin duck and laying ducks during meat and egg productions will be studied to determine carbon emitted from farms, to investigate the rate of carbon massflow from plants to swine, goats, three breed-cross native chicken, pekin duck and laying ducks in the 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 specific objectives of the study on carbon massflow from swine, goat, three breed-cross native chicken, meat and laying duck productions in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces were as the followings.

1.2.1 To estimate the greenhouse gases emission, especially CO_2 and CH_4 related to meat and egg production from livestock in swine, goats, three breed-cross native chicken, pekin duck and laying duck farms.

1.2.2 To study the carbon massflow which was fixed in animal feed and transfer via to animal feeding in swine, goat, three breed-cross native chicken, pekin duck and laying duck farms.

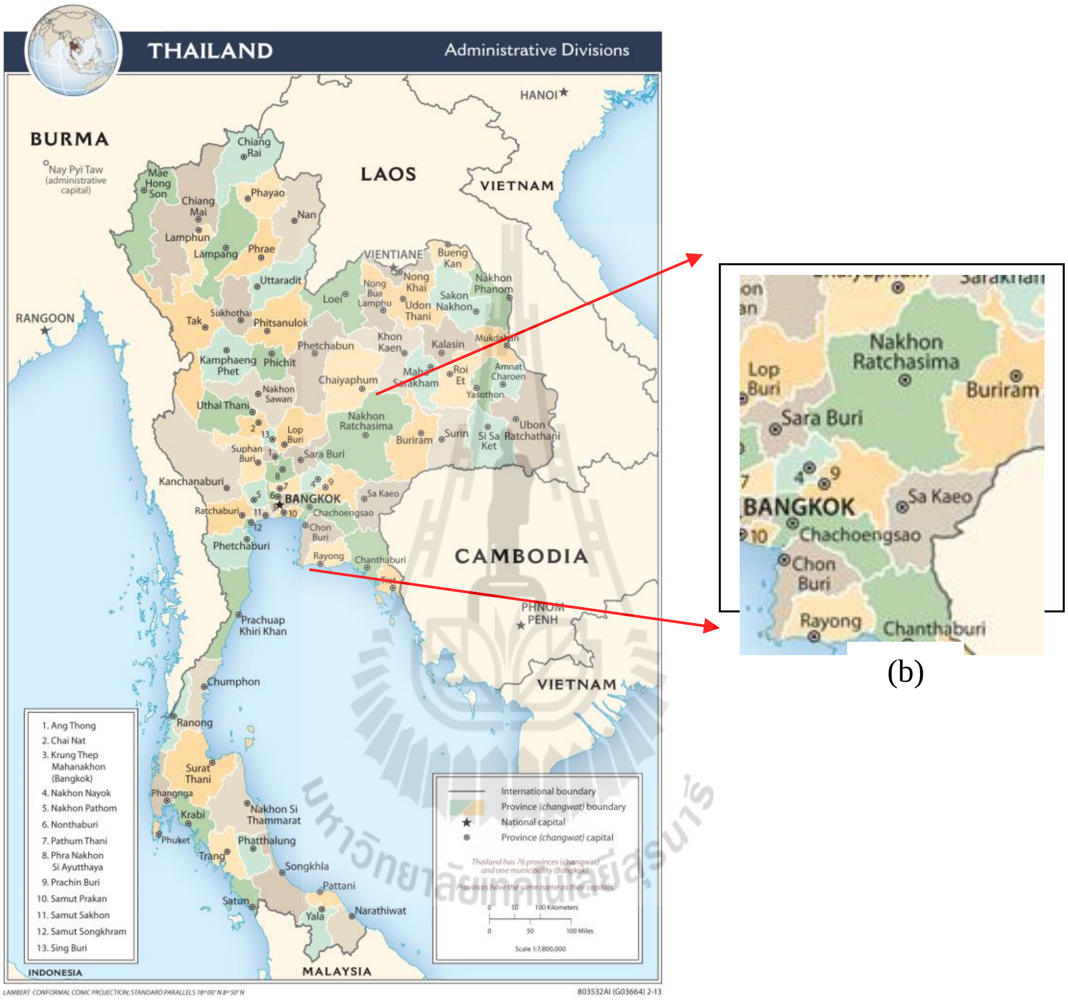
1.2.3 To study carbon from the use of energy in the process of meat and egg production in swine, goat, three breed-cross native chicken, pekin duck and laying duck farms.

1.3 The scope and limitation of the study

1.3.1 The study area

The study on carbon massflow of livestock productions was conducted in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces as shown in Figure 1.1. These provinces represented livestock production of Thailand base on the data of the

Department of Livestock Development (2010). The selected livestock in each province were swine, goats, three breed-cross native chicken, pekin ducks and laying ducks.



(a)

(b)

Figure 1.1 The study areas (https://www.google.co.th).

The study on carbon transfer for food production to develop the carbon emission coefficient from swine, goat, three breed-cross native chicken, pekin and laying duck farms had the scope and limitation of the research as follows:

The differeances of animals in the same species were not considered. They were in mature stages for collecting meat or eggs. All farms and animals were registered. The evaluation and analysis were conducted as the systems were in equilibrium stages using the carbon massflow concept. The steps of food production and carbon transfer are shown in Figure 1.2.

The average of the carbon emitted from energy in housing, transportation and slaughterhouse consisted of 4 main types:

1. The electrical energy or fuel used in animal housing for rearing (kgC/individual/day).
2. The fuel energy for transportation of livestock to slaughterhouses and meat to the markets or factories (kgC/individual/day).
3. The energy for slaughtering animals and heat energy for taking off animal hair and feathers (kgC/individual/day).
4. The energy for freezing meat (kgC/individual/day).

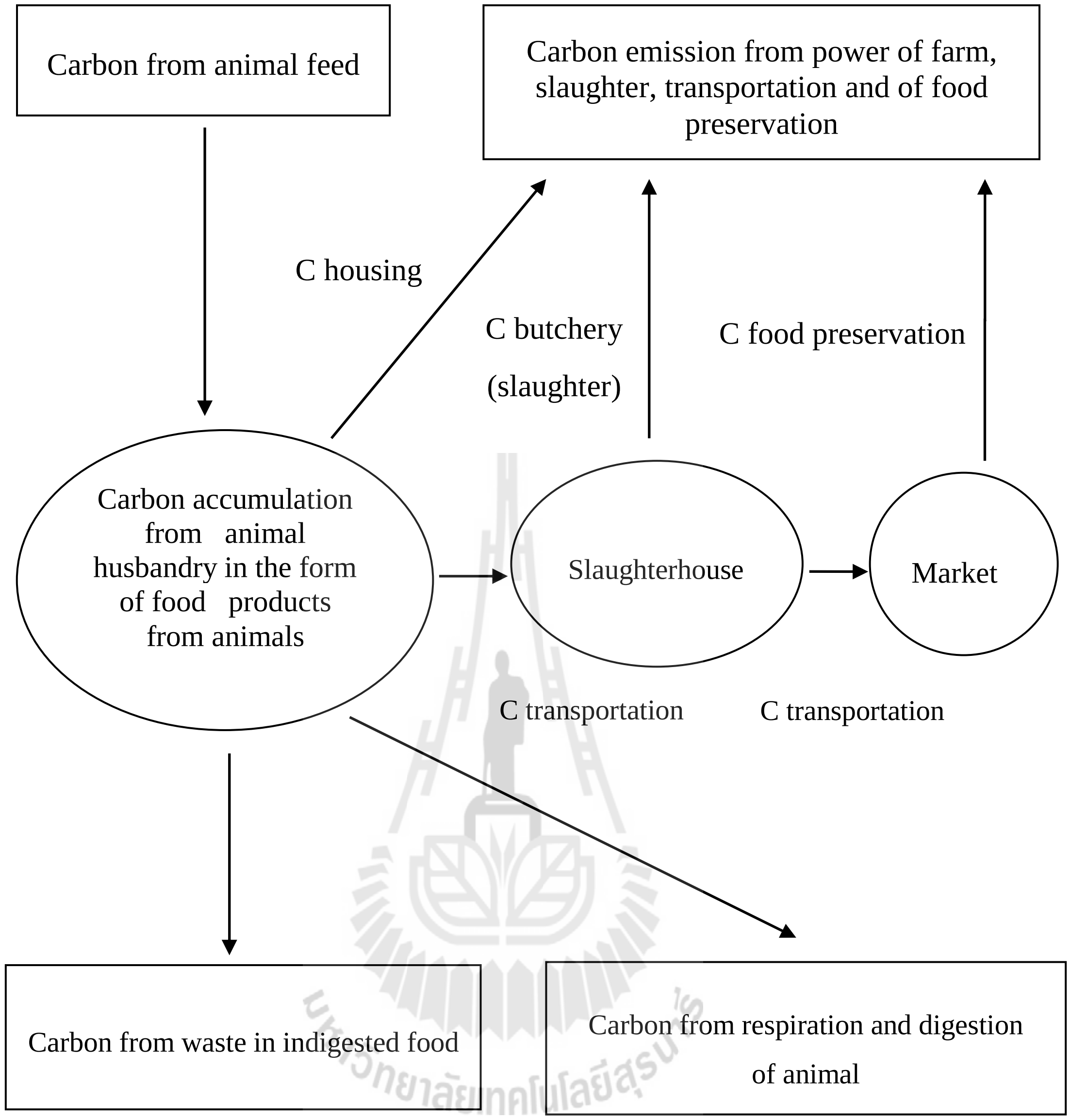


Figure 1.2 The steps of livestock production and the relationship of carbon transfer. (Modified from Keeratiurai, Thanee and Vichairattanatragul, 2013)

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, 37% of CH_4, and 65% of N_2O emissions which is approximately 296 times more potent than CO_2 as a global warming gas. Livestock breeding requires huge water resources and contaminates abyss waters. About 4,664 liters of water to produce 1 serving of beef, but entire vegan meat need only 371 liters of water. Scientists have calculated that we would actually save more water by for going 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 products; largely meat, milk and eggs, is increasing globally. As a result, the world's livestock sector is 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 production can still be increased without damaging the environment which supports that production. An increasing demand for livestock products poses both challenges and opportunities for the reduction of poverty among poor households that have some potential for livestock production (IFAD, 2004; Upton, 2004). However the consumption of livestock products is 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 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, Rosegrant, Steinfeld, Ehui and Courbois, 1999).

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 numbers in extensive production systems in most regions and the bulk of the increase in livestock production 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 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 (FAO, 2006). 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, Kitalyi, Jayasuriya and Smith, 2005).

The data above show the composition of livestock in Thailand in 2007-2008. They indicate that chicken and duck keep their position, while cattle move to the third rank instead of swine. However, the major factors that make overall market value decrease are the increase in fuel prices and cost of production as mentioned in the economic overview 2008 (Department of Livestock Development, 2009).

2.2 Livestock environment interactions and pollution

The main environmental impacts of livestock 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).

2.2.1 Livestock environment interactions

The nature of livestock and environment interactions is dictated mostly by the type of production system. 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).

2.2.1.1 Grazing

Grazing systems are mainly based on native grassland and browse, with no or only limited integration with crops (Peeters, 2009). 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 (Lane, 2014). 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).

2.2.1.2 Mixed farming

In mixed farming systems, livestock and crop activities are integrated. Mixed farming reduces risks from single crop or livestock production, enables more efficient use of labor, and adds value to low value or surplus feed (Meul, Nevens, Reheul and Hofman, 2007). 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 (Tittonell et al., 2009). 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 (Delgado, Rosegrant, Steinfeld, Ehui and Courbois, 1999).

2.2.1.3 Industrial systems

Industrial productions systems are detached from immediate land interms of feed supply and waste disposal (Wackernagel and Rees, 1998). 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 (Craswell, Grote, Henao and Vlek, 2004). This remote land provides feed resources, much of it in the form of grain for example, which may be transported over great distances (Steinfeld, De Haan and Blackburn, 1997).

2.2.2 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, De Haan and Blackburn, 1997). Because of transport costs and market infrastructure, industrial livestock 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 (Rushton, 2009). The unbalance systems in 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 (De Haan, 2001). 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 fewer burdens on the environment (Brandjes, De Wit, Van der Meer and Van Keulen, 1996; Verheijen, Wiersema,, Hulshoff Pol and De Wit, 1996).

2.2.3 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 (Lambina and Meyfroidtb, 2011). 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 products and the consumption of livestock products is currently growing at a faster rate than the increase in world population (Burneya, Davisc and Lobell, 2010). The greater part of the increase in livestock production has come from and will continue to come from increased productivity through intensification (Thornton, 2010). 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, Rosegrant, Steinfeld, Ehui and Courbois, 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 products increases rapidly, an effect which is driven by the rapid growth in per capita incomes, particularly in East and South East Asia (Steinfeld, Wassenaar and Jutzi, 2006). At the same time population growth has led to increases in the number of consumers, particularly in urban zones (Von Braun, 2007). 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, Rosegrant, Steinfeld, Ehui and Courbois, 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 bovine and sheep and goat 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 products have largely stemmed from a shift towards consumption of poultry products (Misra, 1996; Misra, Roy and Hiraoka, 2003).

2.2.4 Waste products

Industrial livestock 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 (De Haan, Steinfeld and Blackburn, 1997). 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 (Steinfeld, Mooney, Schneider and Neville, 2013). 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, De Haan and Blackburn, 1997).

The return of nutrients to the land by the application of manure causes problems due to high water content and high transport cost (Sharpley, Mc Dowell and Kleinman, 2001). 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” (Small, 2013). These nutrient surplus situations also result in high concentrations of heavy metals. These are contained in livestock 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; Eastwood, 2013). 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 (Lim and Teong, 2010).

Drainage of manure and other animal wastes into surface water and leaching from saturated soils is now a feature closely associated with industrial livestock production systems (Loehr, 2012). In areas with high livestock concentrations (e.g. the Netherlands 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, Mooney, Schneider and Neville, 2013).

Nitrate is a potential human health threat especially to infants, causing the condition known as methaemoglobinaemia, also called “blue baby syndrome” (Mensinga, 2003). 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; Fawell and Nieuwenhuijsen, 2014), 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 was around £11 million and off- site damage from soil erosion was put at £14 million.

2.2.5 Processing and slaughter house 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 (Cammarota and Freire, 2006). 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 (Mahajan, 1985). High concentrations of salt and hydrogen supplied present in tannery wastewater have a negative impact on water quality (Judd, 2010). 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, Wiersema, Hulshoff Pol and De Wit, 1996).

Discharge from dairies is often an issue in the developed 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; FAO, 2013). 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).

2.3 Changed pressures on the livestock

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

2.3.1 Changed functions and/or species:

2.3.1.1 From non-food to food functions. The livestock product regard to nutrition, animal source food products can be for great benefit for people.

2.3.1.2 From multipurpose to single purpose livestock production such as change utility chickens to broiler hens.

2.3.1.3 From ruminant to non-ruminants for example moves towards pigs and poultry.

2.3.2 Geographical shifts:

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

2.3.2.2 From rural areas to urban areas.

2.3.3 Structural and technological shifts:

2.2.3.1 From resource-driven to demand driven livestock production.

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

2.3.3.3 From horizontal to vertical integration.

2.3.3.4 From low input to high input livestock production (Fleischhauer, Bayer and Von Lossau, 1997; OECD, 1997; OECD, 1999).

2.4 Environmental impacts

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 (Mc Michael, Powles, Butler and Uauy, 2007). 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. 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 (Evans, 1998). Uninformed policies are responsible for environmental degradation. The following list provides examples where livestock and environment interactions are particularly critical.

2.4.1 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 (Maitra, 2010).

2.4.2 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 (Munasinghe, 1996).

2.4.3 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 (De Bruyn, 2000).

2.4.4 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 (Stillwell and Scholten, 2001).

2.4.5 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 (Rosa and Munasinghe, 2002).

2.4.6 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.

2.4.7 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 (Maitra, 2010).

2.4.8 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 (Stillwell and Scholten, 2001).

2.4.9 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, Bayer and Von Lossau, 1997).

2.5 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 (Van Veenhuizen, 2006). However, development of livestock production technologies which by satisfy the demand for livestock products, whilst at the same time focus on livestock and environment interactions. In addition 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.

2.6 Related researches

2.6.1 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 (2.1)

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, three breed-cross native chicken pekin ducks and laying ducks) (2.2)

Then change ton-methane to ton-CO_2 by multiply by 21 Radioactive forcing CO_2 emission rate = number of animal multiply by carbon emission factor/unit (2.3)

(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 kilogrammeme carbon per individual) or weight of carbon per area in each habitat use for animal rearing in average rearing period (such as kilogrammeme carbon per square meter) as shown in Figure 2.1 and the formula can be:

$$E_{total} = E_{metabolic} + E_{grazing} + E_{housing} + E_{storage} + E_{spreeding} \quad (2.4)$$

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 such as grass and houses.

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

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

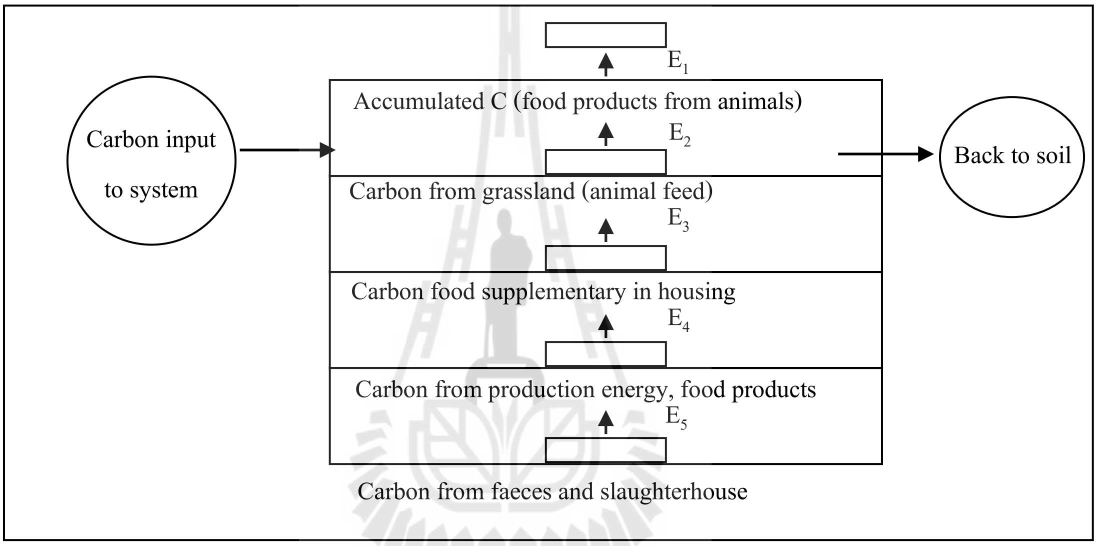


Figure 2.1 Carbon emission systems in each activity of livestock farming (UNECE, 2004).

$$E_{total} = n_{animal} \times (EF_{metabolic} + EF_{grazing} + EF_{housing} + EF_{storage} + EF_{spreading}) \quad (2.5)$$

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).

2.6.2 The impact of animal production environment and carbon change

The animal production or livestock usually have impacts on the environment such as soil, water and air quality. The impact from animal productions to the atmosphere is 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 emissions are usually from fuel used in agricultural activity and little from livestock (less than 5%). It is an important problem because CO_2 from livestock 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, Richard and Usengumuremyi, 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 release with faeces (faecal organic matter excretion (FOME)) (Guerin, Richard, Lefevre, Friot and Mbaye, 1989). Carbon concentration from faeces is studied by oven drying it at 550 ^{o}C and then the chromatography method will be used (Thermoques NC Soil 200). The use of carbon in animal production that takes 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 is 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, Chotte, Masse, Laurent and Feller, 2002).

The gases from animal breathing in cattle is measured 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 (Hashizume, Aysegul and Sadriye, 1963; Kawashima, Terada and Shibata, 2000; Liang, Terada and Hamaguchi, 1989).

2.6.3 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 Study areas

The research on mass transfer of carbon from food production of livestock was conducted in each district and sub-commune of Nakhon Ratchasima, Chon Buri and Prachin Buri provinces. The districts and sub-communes were used as the “districts” for the convenience. These three provinces have raised quite high density of livestock in Thailand as shown in Figures 3.1 to 3.4. This study focused on herbivorous animals, meat, eggs and faeces which were taken from each animal species. The studied livestock were divided into 3 groups such as monogastric; swine, small ruminant; goats and poultry; three breed-cross native chicken, pekin ducks and laying ducks.

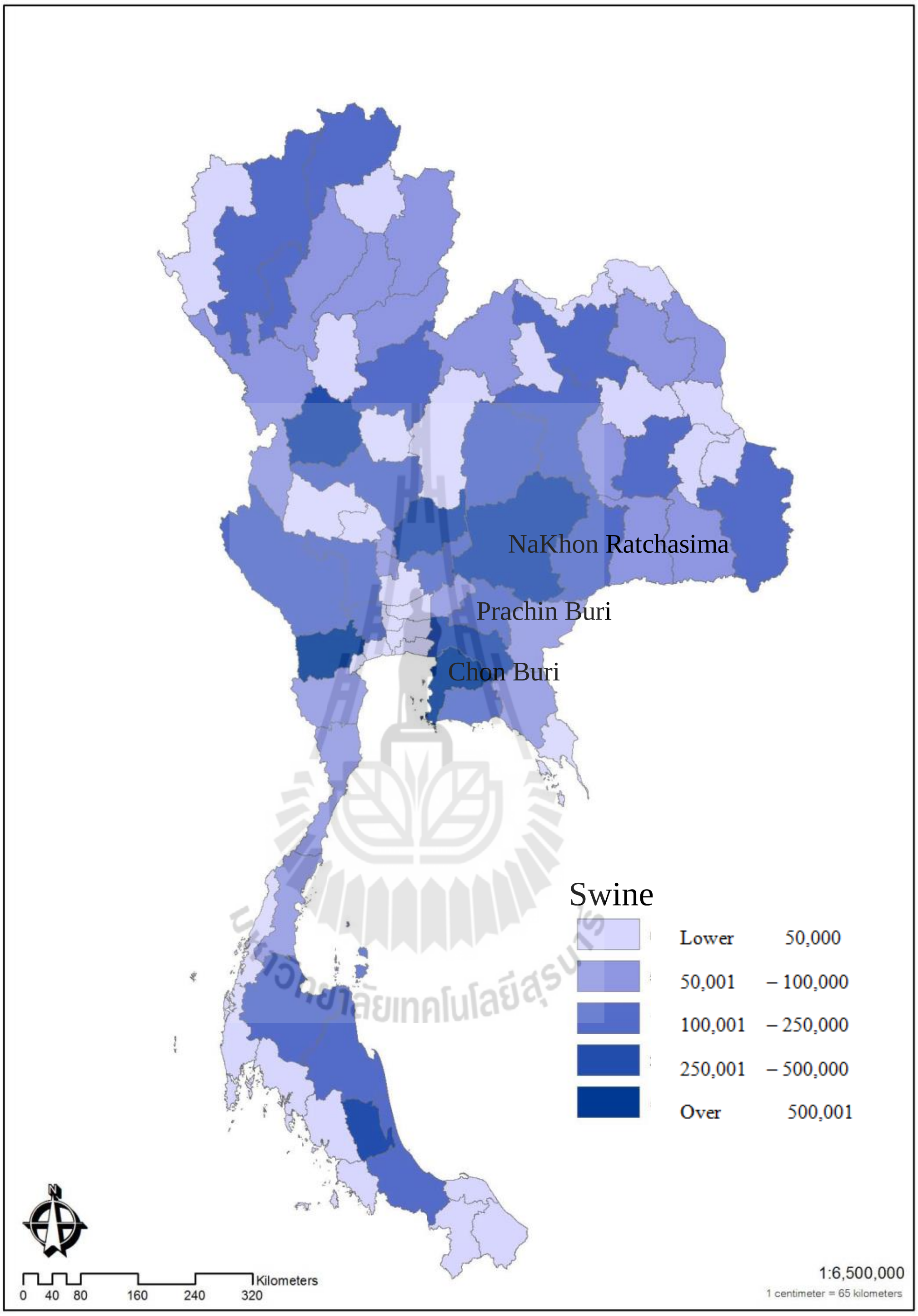


Figure 3.1 Map of Thailand shows density of swine production in 2013.

(Department of Livestock Development, 2010)

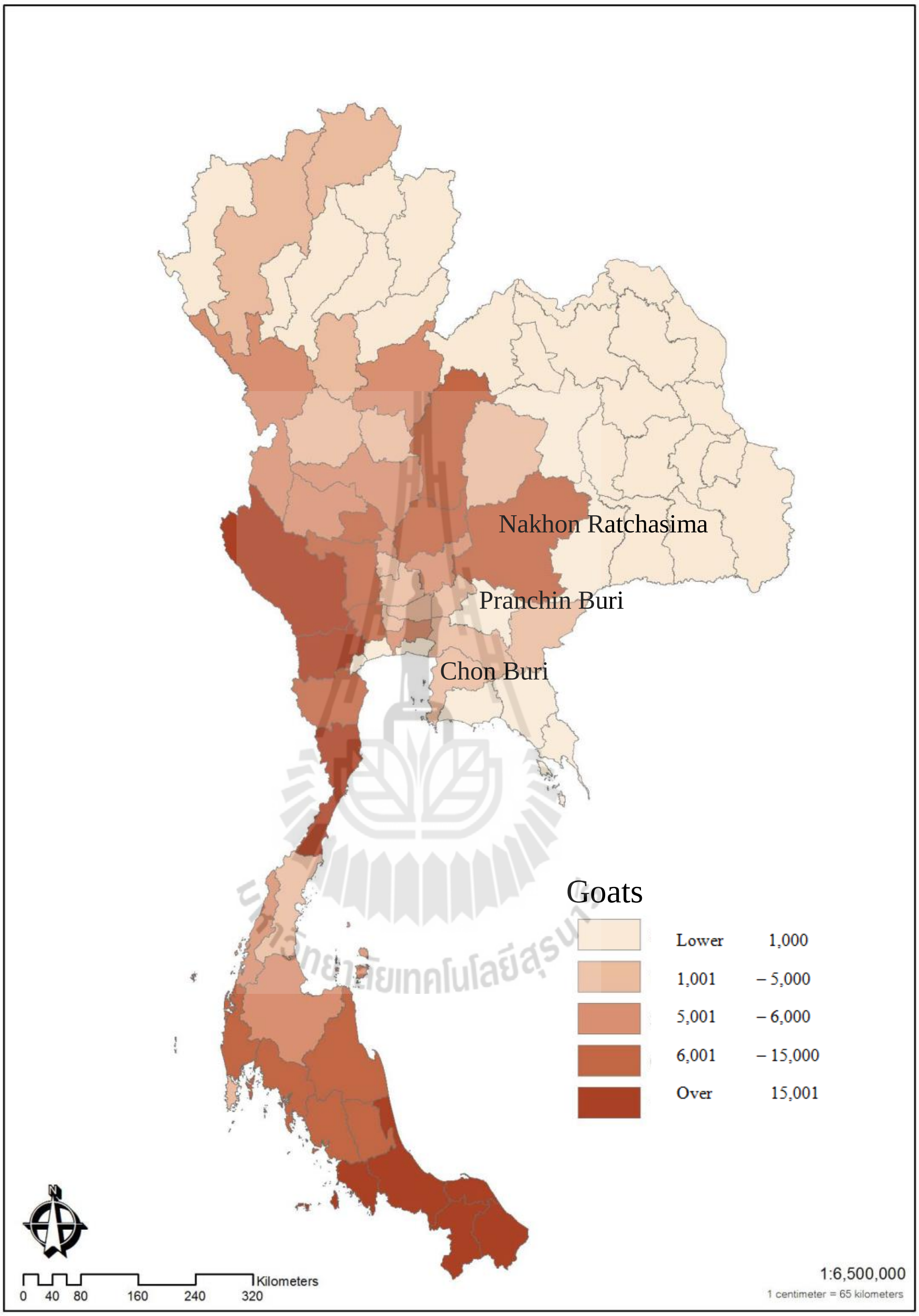


Figure 3.2 Map of Thailand shows density of goat production in 2013.

(Department of Livestock Development, 2010)

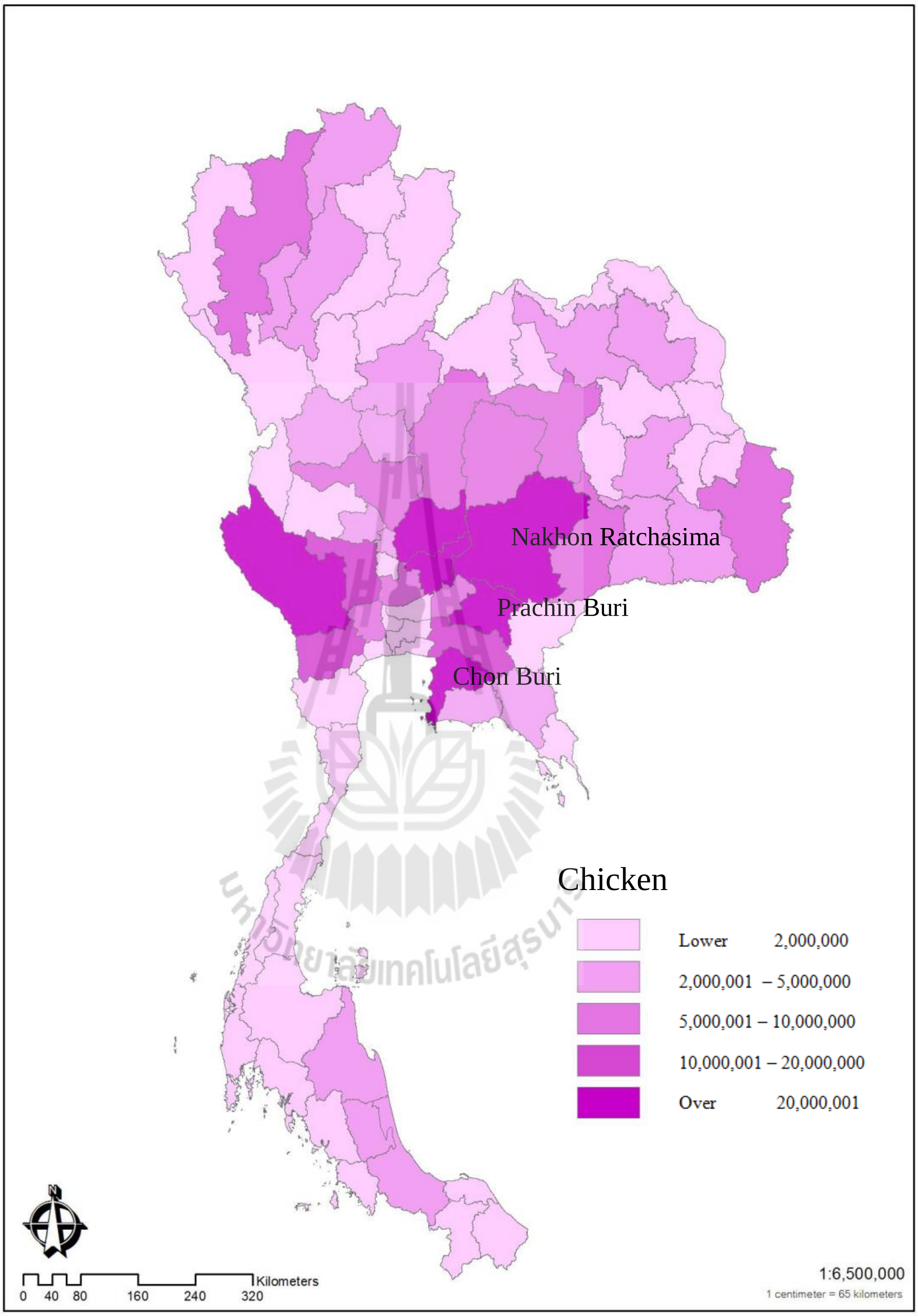


Figure 3.3 Map of Thailand shows density of chicken production in 2013.

(Department of Livestock Development, 2010)

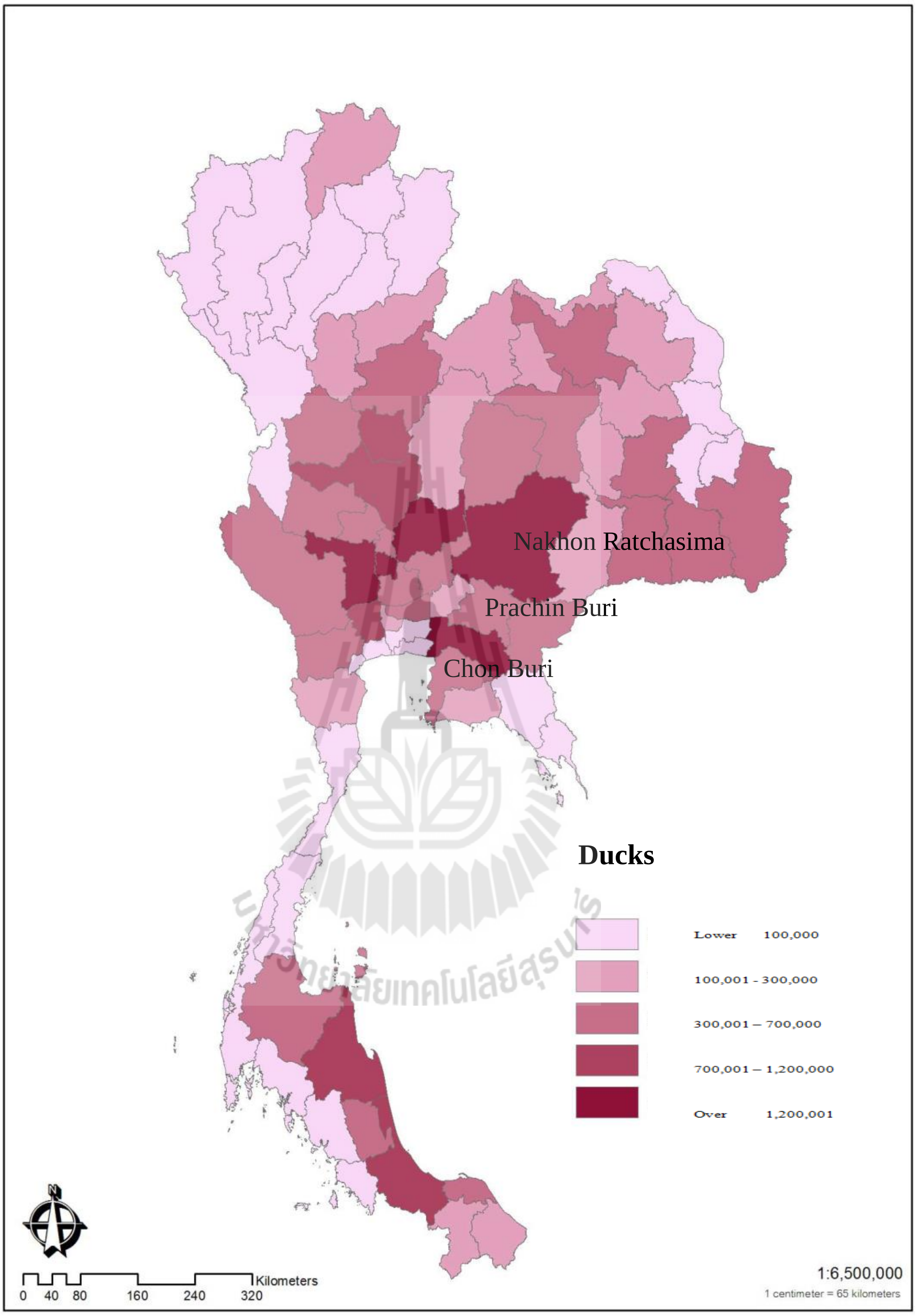


Figure 3.4 Map of Thailand shows density of ducks production in 2013.

(Department of Livestock Development, 2010)

3.2 The number of samples

The numbers of farms, swine, goats, three breed-cross native chicken, pekin ducks and laying ducks in each district of selected provinces were calculated by determining the numbers of farms of swine, goats, three breed-cross native chicken, pekin ducks and laying ducks in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces at 95% confidence level (Yamane, 1973; Cavana, Delahaye and Sekaran, 2001). Therefore, the sample groups were calculated by Taro Yamane's formula (Yamane, 1973) as follow:

$$n = \frac{N}{1 + Ne^2} \tag{3.1}$$

Where;

n = Sample size

N = Population size

E = The error of sampling

The calculation showed that sample size were 400 swine farms, 400 swine, 311 goat farms, 400 goats, 400 three breed-cross native chicken farms, 400 three breed-cross native chicken, 400 pekin duck farms, 400 pekin ducks and 400 laying duck farms, 400 laying ducks. Animal feed, eggs, meat and faeces were collected and transferred to the laboratory at Suranaree University of Technology for measurements and analyses. Carbon dioxide was measured from living swine, goats, three breed-cross native chicken, pekin ducks and laying ducks at the farms. The number of farms and animals are shown in Tables 3.1 to 3.5.

Table 3.1 The number of farms and number of swine in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces.

Province	District	Swine			
		Number of Animal		Number of Farm	
		Population	Sample	Population	Sample
Nakhon Ratchasima	Mueang Nakhon Ratchasima	42,627	2	350	2
	Ban Lueam	-	-	-	-
	Bua Lai	550	1	52	1
	Bua Yai	2,378	1	135	1
	Chakkarat	4,937	2	138	2
	Chaloem Phra Kiat	544	1	49	1
	Chok Chai	4,819	2	90	2
	Chum Phuang	2,515	2	252	2
	Dan Khun Thot	6,564	3	137	3
	Huai Thalaeng	2,914	2	1,090	2
	Kaeng Sanam Nang	1,383	1	125	1
	Kham Sakaesaeng	1,004	1	41	1
	Kham Thale So	414	1	35	1
	Khon Buri	231	1	15	1
	Khong	857	1	87	1
	Lam Thamenchai	3,537	1	396	1
	Mueang Yang	993	1	186	1
	Non Daeng	849	1	57	1
	Non Sung	2,761	1	195	1
	Non Thai	20,175	9	134	9
	Nong Bun Mak	21,376	1	343	1
	Pak Chong	153,186	68	68	68
	Pak Thong Chai	4,617	2	246	2
	Phimai	415	2	38	2
	Prathai	819	1	119	1
	Phra Thong Kham	992	1	198	1
	Sida	30	-	-	-
	Sikhio	152	1	12	1
	Soeng Sang	1,070	1	15	1
	Sung Noen	10,738	5	164	5
	Thepharak	372	1	34	1
	Wang Nam Khiao	599	1	109	1

Table 3.1 The number of farms and number of swine in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (Continued).

Province	District	Swine			
		Number of Animal		Number of Farm	
		Population	Sample	Population	Sample
Chon Buri	Mueang Chon Buri	34	-	6	-
	Ban Bueng	149,204	67	25	67
	Bang Lamung	6,131	3	18	3
	Bo Thong	132,135	59	79	59
	Ko Chan	4,633	1	4	1
	Ko Si Chang	-	-	-	-
	Nong Yai	21,280	10	5	10
	Phan Thong	43,700	19	5	19
	Phanat Nikhom	129,414	58	79	58
	Sattahip	89	-	3	-
	Si Racha	-	-	-	-
Prachin Buri	Mueang Prachin Buri	16,991	8	34	8
	Ban Sang	11,510	5	4	5
	Kabin Buri	46,738	30	34	30
	Na Di	27,588	12	45	12
	Prachantakham	19,349	9	46	9
	Si Maha Phot	145	-	8	-
	Si Mahosot	2,120	1	3	1
Total		**905,479**	**400**	**5,308**	**400**

Table 3.2 The number of farms and number of goats in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces.

Province	District	Goat			
		Number of Animal		Number of Farm	
		Population	Sample	Population	Sample
Nakhon Ratchasima	Mueang Nakhon Ratchasima	114	6	7	6
	Ban Lueam	-	-	-	-
	Bua Lai	-	-	-	-
	Bua Yai	70	3	1	3
	Chakkarat	-	-	-	-
	Chaloem Phra Kiat	-	-	-	-
	Chok Chai	301	12	12	12
	Chum Phuang	-	-	-	-
	Dan Khun Thot	1,136	47	21	47
	Huai Thalaeng	-	-	-	-
	Kaeng Sanam Nang	300	12	8	12
	Kham Sakaesaeng	12	1	1	1
	Kham Thale So	320	13	8	13
	Khon Buri	289	13	15	13
	Khong	68	3	3	3
	Lam Thamenchai	-	-	-	-
	Mueang Yang	869	36	22	36
	Non Daeng	-	-	-	-
	Non Sung	127	5	12	5
	Non Thai	214	9	11	9
	Nong Bun Mak	528	22	17	22
	Pak Chong	2,580	108	64	108
	Pak Thong Chai	132	6	7	6
	Phimai	-	-	-	-
	Prathai	-	-	-	-
	Phra Thong Kham	-	-	-	-
	Sida	-	-	-	-
	Sikhio	96	4	5	4
	Soeng Sang	68	2	2	2
	Sung Noen	-	-	-	-
	Thepharak	-	-	-	-
	Wang Nam Khiao	4	1	1	1

Table 3.2 The number of farms and number of goats in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (Continued).

Province	District	Goat			
		Number of Animal		Number of Farm	
		Population	Sample	Population	Sample
Chon Buri	Mueang Chon Buri	60	3	31	3
	Ban Bueng	-	-	-	-
	Bang Lamung	549	24	25	24
	Bo Thong	459	19	22	19
	Ko Chan	76	3	4	3
	Ko Si Chang	-	-	-	-
	Nong Yai	55	2	1	2
	Phan Thong	18	1	1	1
	Phanat Nikhom	141	6	6	6
	Sattahip	109	5	3	5
	Si Racha	115	4	8	4
Prachin Buri	Mueang Prachin Buri	30	2	4	2
	Ban Sang	150	6	1	6
	Kabin Buri	485	20	5	20
	Na Di	-	-	-	-
	Prachantakham	12	1	2	1
	Si Maha Phot	16	1	1	1
	Si Mahosot	-	-	-	-
Total		**9,503**	**400**	**331**	**400**

Table 3.3 The number of farms and number of three breed-cross native chick in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces.

Province	District	Three cross breed native chicken			
		Number of Animal		Number of Farm	
		Population	Sample	Population	Sample
Nakhon Ratchasima	Mueang Nakhon Ratchasima	289,900	25	11,737	25
	Ban Lueam	47,517	4	2,495	4
	Bua Lai	47,009	5	2,333	5
	Bua Yai	211,804	18	11,938	18
	Chakkarat	131,837	11	5,647	11
	Chaloem Phra Kiat	52,003	5	2,688	5
	Chok Chai	100,461	10	4,661	10
	Chum Phuang	145,383	13	6,786	13
	Dan Khun Thot	133,148	12	5,930	12
	Huai Thalaeng	97,229	8	4,830	8
	Kaeng Sanam Nang	88,506	8	3,066	8
	Kham Sakaesaeng	106,418	10	3,636	10
	Kham Thale So	66,133	6	2,361	6
	Khon Buri	108,168	9	6,283	9
	Khong	151,264	13	5,745	13
	Lam Thamenchai	66,230	6	2,422	6
	Mueang Yang	34,612	4	2,327	4
	Non Daeng	54,335	5	2,650	5
	Non Sung	132,329	12	5,634	12
	Non Thai	180,607	16	7,410	16
	Nong Bun Mak	101,556	10	4,235	10
	Pak Chong	188,433	16	9,602	16
	Pak Thong Chai	143,301	12	4,508	12
	Phimai	96,594	8	4,225	8
	Prathai	111,980	10	4,998	10
	Phra Thong Kham	222,143	16	2,755	16
	Sida	71,310	7	1,809	7
	Sikhio	91,517	8	3,910	8
	Soeng Sang	246,846	19	4,304	19
	Sung Noen	188,279	16	6,196	16
	Thepharak	78,507	7	3,560	7
	Wang Nam Khiao	64,873	6	2,802	6

Table 3.3 The number of farms and number of three breed-cross native chick in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (Continued).

Province	District	Three cross breed native chicken			
		Number of Animal		Number of Farm	
		Population	Sample	Population	Sample
	Mueang Chon Buri	12,494	1	1,131	1
	Ban Bueng	70,777	7	1,527	7
	Bang Lamung	44,935	4	586	4
	Bo Thong	21,036	2	884	2
	Ko Chan	43,707	4	1,976	4
Chon Buri	Ko Si Chang	13,267	1	647	1
	Nong Yai	11,408	1	557	1
	Phan Thong	21,719	1	1,247	1
	Phanat Nikhom	97,442	8	3,751	8
	Sattahip	24,308	2	884	2
	Si Racha	13,267	1	647	1
	Mueang Prachin Buri	83,733	7	1,227	7
	Ban Sang	27,631	2	794	2
	Kabin Buri	138,462	12	2,316	12
Prachin Buri	Na Di	8,297	1	783	1
	Prachantakham	29,503	3	1,028	3
	Si Maha Phot	55,720	5	834	5
	Si Mahosot	36,656	3	411	3
Total		**4,604,594**	**400**	**174,713**	**400**

Table 3.4 The number of farms and number of pekin ducks in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces.

Province	District	Pekin duck			
		Number of Animal		Number of Farm	
		Population	Sample	Population	Sample
Nakhon Ratchasima	Mueang Nakhon Ratchasima	-	-	-	-
	Ban Lueam	-	-	-	-
	Bua Lai	-	-	-	-
	Bua Yai	-	-	-	-
	Chakkarat	-	-	-	-
	Chaloem Phra Kiat	-	-	-	-
	Chok Chai	34,583	6	25	6
	Chum Phuang	-	-	-	-
	Dan Khun Thot	-	-	-	-
	Huai Thalaeng	8,603	2	2,566	2
	Kaeng Sanam Nang	-	-	-	-
	Kham Sakaesaeng	-	-	-	-
	Kham Thale So	13,582	3	31	3
	Khon Buri	12,515	2	3	2
	Khong	-	-	-	-
	Lam Thamenchai	7,355	2	653	2
	Mueang Yang	-	-	-	-
	Non Daeng	-	-	-	-
	Non Sung	-	-	-	-
	Non Thai	200,819	40	169	40
	Nong Bun Mak	-	-	-	-
	Pak Chong	-	-	-	-
	Pak Thong Chai	135,189	26	56	26
	Phimai	8,152	2	258	2
	Prathai	-	-	-	-
	Phra Thong Kham	32,413	6	164	6
	Sida	-	-	-	-
	Sikhio	-	-	-	-
	Soeng Sang	13,104	3	491	3
	Sung Noen	639,874	118	162	118
	Thepharak	-	-	-	-
	Wang Nam Khiao	-	-	-	-

Table 3.4 The number of farms and number of pekin ducks in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (Continued).

Province	District	Pekin duck			
		Number of Animal		Number of Farm	
		Population	Sample	Population	Sample
Chon Buri	Mueang Chon Buri	11,212	2	60	2
	Ban Bueng	38,736	7	21	7
	Bang Lamung	11,268	2	14	2
	Bo Thong	35,605	7	11	7
	Ko Chan	16,000	3	2	3
	Ko Si Chang	-	-	-	-
	Nong Yai	70,054	12	4	12
	Phan Thong	34,718	4	18	4
	Phanat Nikhom	164,791	30	64	30
	Sattahip	-	-	-	-
	Si Racha	-	-	-	-
Prachin Buri	Mueang Prachin Buri	96,536	18	45	18
	Ban Sang	-	-	-	-
	Kabin Buri	500,784	91	24	91
	Na Di	-	-	-	-
	Prachantakham	1,048	1	70	1
	Si Maha Phot	67,176	12	29	12
	Si Mahosot	-	-	-	-
Total		**2,154,117**	**399**	**4,940**	**399**

Table 3.5 The number of farms and number of laying ducks in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces.

Province	District	Laying Duck			
		Number of Animal		Number of Farm	
		Population	Sample	Population	Sample
Nakhon Ratchasima	Mueang Nakhon Ratchasima	10,788	12	301	12
	Ban Lueam	2,384	3	186	3
	Bua Lai	1,709	1	144	1
	Bua Yai	8,097	9	558	9
	Chakkarat	5,740	6	190	6
	Chaloem Phra Kiat	2,236	2	143	2
	Chok Chai	4,012	4	150	4
	Chum Phuang	39,716	43	1,103	43
	Dan Khun Thot	1,904	2	35	2
	Huai Thalaeng	-	-	-	-
	Kaeng Sanam Nang	6,365	8	316	8
	Kham Sakaesaeng	4,574	4	239	4
	Kham Thale So	2,453	3	99	3
	Khon Buri	-	-	-	-
	Khong	7,555	8	359	8
	Lam Thamenchai	4,806	5	377	5
	Mueang Yang	14,845	16	365	16
	Non Daeng	3,195	3	244	3
	Non Sung	26,370	30	940	30
	Non Thai	5,493	6	394	6
	Nong Bun Mak	446	1	46	1
	Pak Chong	2,440	3	62	3
	Pak Thong Chai	16,577	18	317	18
	Phimai	6,069	7	232	7
	Prathai	7,261	8	400	8
	Phra Thong Kham	947	1	174	1
	Sida	2,402	2	162	2
	Sikhio	2,379	3	38	3
	Soeng Sang	3,838	4	214	4
	Sung Noen	9,618	10	672	10
	Thepharak	1,219	1	94	1
	Wang Nam Khiao	214	1	17	1

Table 3.5 The number of farms and number of laying ducks in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (Continued).

Province	District	Laying Duck			
		Number of Animal		Number of Farm	
		Population	Sample	Population	Sample
Chon Buri	Mueang Chon Buri	14,280	15	115	15
	Ban Bueng	43,590	47	29	47
	Bang Lamung	832	1	20	1
	Bo Thong	142	1	8	1
	Ko Chan	-	-	-	-
	Ko Si Chang	-	-	-	-
	Nong Yai	-	-	-	-
	Phan Thong	75,057	81	9	81
	Phanat Nikhom	10,683	12	108	12
	Sattahip	2,719	3	17	3
	Si Racha	-	-	-	-
Prachin Buri	Mueang Prachin Buri	3,684	4	116	4
	Ban Sang	1,135	1	43	1
	Kabin Buri	3,528	4	99	4
	Na Di	-	-	-	-
	Prachantakham	1,706	2	93	2
	Si Maha Phot	4,775	5	16	5
	Si Mahosot	-	-	-	-
Total		**367,783**	**400**	**9,244**	**400**

3.3 Methodology

The procedure of the study on carbon emission to develop carbon footprints from meat and egg production of swine, goat, three breed-cross native chicken, pekin duck and laying duck farms was divided into 2 steps as follows:

3.3.1 Field information

The purpose of this step was to collect primary data from livestock farms, factories and slaughterhouses in Nakhon Ratchasima, Chon Buri and Prachin

Buri provinces. The information including 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 animals were in meat and egg-laying stages. Sexes, ages, variety and status such as pregnant or unwell stages were not considered.

The study was focused on five livestock; swine, goats, three breed-cross native chicken, pekin duck and laying ducks. These animals must be existed on the farmer farms and all studied animals must be 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 should be 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 five animals during feeding duration of each animal. This procedure was to investigate the net carbon transference from plants to animals (minus by carbon content in animal faeces) and then accumulated or fixed in animals in the forms of meat and eggs. The four main important energy used were as 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 used 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 the animals to slaughterhouses and transportation of meat to markets and meat processing factories.

3.3.2 Samples analysis in laboratory

The carbon content was studied by using CHN 628 Elemental Analyzer and Gas Analyzer. Samples, including food plants, meat of swine, goats, three breed-cross native chicken, pekin and laying ducks 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, Delahaye and Sekaran, 2000; Marks, 1982). Samples of meat, eggs, faeces and food plants or animal feed were analyzed to investigate their characteristics in laboratory as summarized in Table 3.6.

The data of carbon content from the laboratory then used as sources to study the average of carbon from livestock activities (kg.C/kg of livestock product/day) and to find carbon transfer rate from plants to animals. The carbon emission in terms of CO_2 and CH_4 was also investigated (UNECE, 2004).Thus, the carbon emission is shown in the formula 3.2.

$$E_{total} = n_{animal} \times (EF_{metabolic} \times EF_{spreading} \times EF_{energy\ equivalent}) \qquad (3.2)$$

Where:

E_{total} = The total of carbon emission (kg.C/day).

n_{animal} = The number of livestock animal.

$EF_{metabolic}$ = The carbon emission from the respiration of livestock animal (kg.C/kg of livestock production/day).

$EF_{spreading}$ = The carbon emission from faeces of livestock animal (kg.C/kg of livestock production/day).

$EF_{energy\ equivalent}$ = The carbon emission from energy used in livestock meat and egg productions for example fuel used for transportation, electricity used in farm management, in slaughterhouse and the market including electric used for frozen livestock meat production (kg.C/kg of livestock production/day).

Table 3.6 Analyzing methods to study food plant, meat, egg and faeces.

Parameter	**Method**	**Rreference**
% Moisture	Know sampling dried weight, dried at 103-105 ^oC for 24 hrs.	Manlay et al. (2004a)
Carbon content (C)	CHN 628 Elemental Analyzer and Gas Analyzer Respiration Trial System	Manlay et al. (2004b) Kawashima et al. (2000a)
Volatile solid	Lost weight from known weight or volume of samples, incinerate at 550 ^oC for 30 min.	APHA, AWWA, WEF (1992)
Fixed solid	Remain weight from known weight or volume, incinerate at 550 ^oC for 30 min.	APHA, AWWA, WEF (1992)
Weight	Weigh swine, goats, using swine and goats weighing tapes.	Bunyavejchewin et al. (1985)

3.3.3 The calculations of energy used and carbon contents

The calculations of energy used and carbon contents were as follows:

3.3.3.1 The carbon input (C-input) from animal food for feeding to the biomass of five livestock were analyzed.

3.3.3.2 The carbon emission rate (C-emission) was analyzed from energy used in livestock farms and dry faeces, as well as the C-emission in form CO_2 and CH_4 for digestion and respiration of livestock.

3.3.3.3 The carbon fixation rate (C-fixation) was studied from livestock meat productions and egg productions.

3.3.3.4 The efficiency in the carbon used of livestock was studied.

3.3.3.5 The proportion of environmental impacts compare to the same C-fixation and the amount of carbon in the same livestock food was calculated.

3.3.3.6 The amounts of electricity, petroleum and liquefied petroleum gas (LPG) used for feeding machines, automatic pumps, heaters for increasing temperature for small livestock, fan for decreasing temperature for livestock and storage of the frozen livestock meat productions were investigated.

3.3.3.7 The amount of energy used for transportation such as transporting of feeding and small livestock animals to farms, transporting of livestock animals to slaughterhouses, transportings meat and egg productions to the markets was also investigated.

3.3.3.8 The estimates of energy used and carbon contents for each task were summed and presented at kilogramme of carbon contents per kilogramme of livestock per day. The scope of studies is shown in Figure 3.5.

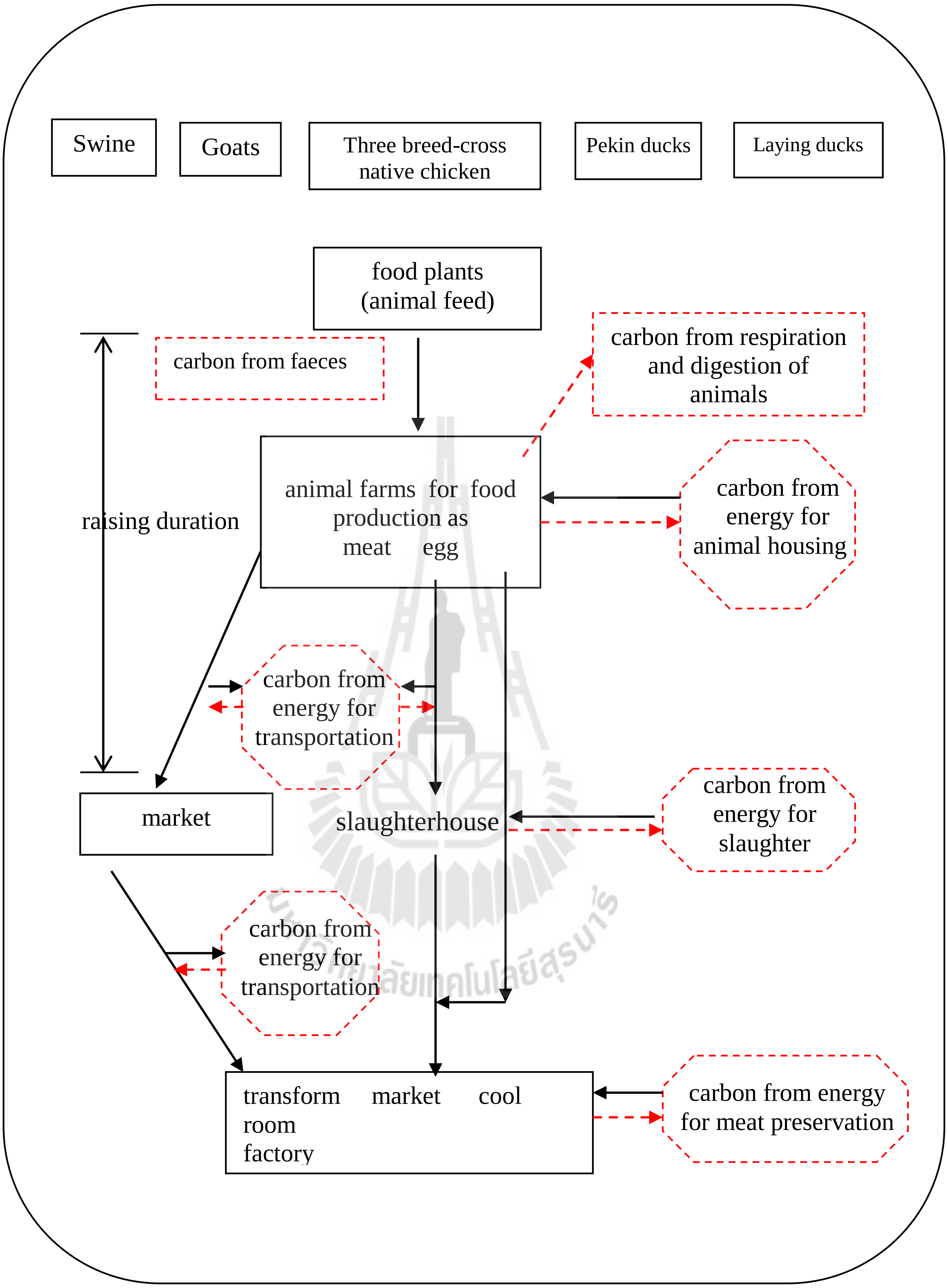


Figure 3.5 Scope of study on carbon transfer and carbon emission from livestock productions.

3.4 Data analyses

Data of all carbons which related with food productions such as carbon in animal feed, meat, eggs and carbon in forms of 4 groups of energy use in production were used to analyze the efficiency of carbon use (kg.C/individual/year) in each step. The results explained the ratio of carbon emission to carbon fixation in form of food and explained the environmental impact from carbon emission. Moreover, the rate of carbon content changes per unit of animal food plants to become food products could be evaluated. The analyses of some important figures were as follows:

3.4.1 Carbon emission rate (C-emitted) was total carbon that secreted in the form of carbon from faeces (C-output) and carbon from gasses for example CO_2 and CH_4 from animal respiration and digestion (C-emission) per time. C-emitted for each animal is shown in the formula 3.1

$$\text{C-emitted} = (\text{C output} + \text{C emissions}) \text{ per time} \tag{3.1}$$

3.4.2 The carbon fixation rate (C-fixation) from animal feed to livestock animals by food weight and livestock animal weight compare to time is shown in the formula 3.2.

$$\text{C-fixation} = (\text{C input} - \text{C emitted}) \text{ per time} \tag{3.2}$$

3.4.3 The comparison of the efficiency in the carbon fixation from meat and egg productions of each animal to consider that which kind of livestock animal was more suitable for meat and eggs production. Also, the livestock animals should have higher efficiency in carbon fixation than other livestock animals. It could be calculated as the formula 3.3.

$$\text{C- fixation efficiency} = \frac{(\text{C input} - \text{C emitted})}{\text{C input}} \quad (3.3)$$

3.4.4 The analysis for ranking the importance of each livestock animal kind for the production of meat and egg from swine, goats, three breed-cross native chicken, pekin ducks and laying ducks which showed the least impact on environment was further analyzed. The comparison of the carbon from livestock animals and energy used within the livestock farms for farm management, transportation, storage of livestock production, including carbon fixation in livestock production are shown in the formula 3.4 and formula 3.5.

$$\begin{array}{l} \text{Ratio of environment impact} \\ \text{(compared to the same level of C-fixation)} \end{array} = \frac{\text{C emitted}}{\text{C fixation}} \quad (3.4)$$

$$\begin{array}{l} \text{Ratio of environment impact} \\ \text{(compared to amount of feed)} \end{array} = \frac{\text{C emitted}}{\text{C input}} \quad (3.5)$$

Where:

Carbon fixation = carbon from livestock meat and egg

Carbon emitted = carbon from respiration, digestion and faeces

Carbon input = carbon from artificial diet

3.5 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 livestock groups 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

4.1 Rate of carbon massflow in livestock production

4.1.1 Carbon input, carbon fixation and carbon emission in each livestock

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

The results found that the rate of carbon transference from animal feed for feeding in swine, goats, three breed-cross native chicken, pekin ducks and laying ducks in the Nakhon Ratchasima Chon Buri, and Prachin Buri provinces were 0.942±0.04 kg.C/swine/day, 1.13±1.68 kg.C/goat/day, 0.047±0.48 kg.C/three breed-cross native chicken/day, 0.114±0.57 kg.C/pekin duck/day and 0.143±0.57 kg.C/laying duck/day, respectively. Carbon fixation was calculated by mass balance. The C-input minus the carbon emission in faeces, enteric fermentation, and respiration (C-emission) was the carbon mass fixed in the body (C-fixation). The carbon fixation of swine, goats, three breed-cross native chickens, pekin ducks and laying ducks were 0.641±0.63 kg.C/swine/day, 0.713±1.14 kg.C/goat/day, 0.031±0.49 kg.C/three breed-cross native chick/day, 0.086±0.81 kg.C/pekin duck/day and

0.094±1.18 kg.C/laying duck/day, respectively. The carbon emission (C-emitted) from faeces, enteric fermentation, and respiration were 0.275±0.58 kg.C/swine/day, 0.383±1.46 kg.C/goat/day, 0.016±0.63 kg.C/three breed-cross native chicken/day, 0.035±0.79 kg.C/pekin duck/day and 0.046±1.37 kg.C/laying duck/day, respectively. The swine had highest carbon fixation efficiency (68.79%), followed by pekin ducks (67.11%), laying ducks (65.74%), three breed-cross native chickens (64.85%) and goats (63.09%), respectively. Nevertheless, the laying ducks had the highest carbon emission from the same weight at 27.54×10^{-3} kg.C/laying duck/day, followed by three breed-cross native chicken 13.33×10^{-3} kg.C/three breed-cross native chicken/day, pekin ducks 10.77×10^{-3} kg.C/pekin duck/day, goats 10.40×10^{-3} kg.C/goat/day and swine 2.78×10^{-3} kg.C/swine/day, respectively. The rate of carbon input from animal feed to livestock animal by consumption including carbon fixation in livestock animal bodies and faeces during rearing duration are shown in Tables 4.1 to 4.3 and Table 4.11.

Each type of livestock animal emitted different average total carbon per kilogramme which a goat had the highest C-input because goat consume the roughage and low nutrient intake compere with a swine, a three breed-cross native chicken, a pekin duck and a laying duck. Nonetheless, total carbon emission per day from a goat was 0.383±1.46 kg.C/goat/day. Lowest of carbon content was in the form of faeces 56.21% of all carbon emission as shown in Figure 4.1 and 4.2. Carbon in form of carbon dioxide (CO_2) and methane (CH_4) from respiration and excretion of goat was the highest at 43.51% of all carbon emission. One of swine, three breed-cross native chicken, pekin duck and laying duck had close carbon emission at 0.275±0.58 kg.C/swine/day, 0.016±0.63 kg.C/three breed-cross native chicken/day, 0.035±0.79 kg.C/pekin duck/day and 0.046±1.37 kg.C/laying duck/day, respectively. The carbon content were in the faeces of swine, three breed-cross native chicken, pekin duck and laying duck at 61.14%, 74.19%, 68.71% and 75.95%, respectively. While the carbon content in form of CO_2 and CH_4 from respiration and digestion of swine, three breed-cross native chickens, pekin ducks and laying ducks were at 38.14%, 22.58%, 22.86% and 26.67 of all total carbon emission, respectively as shown in Table 4.5 and Figure 4.1.

The average amount of carbon was released in the form of CO_2 and CH_4 from faeces, digestion and respiration of each animal as showed in Tables 4.4 and 4.6. The proportion of CO_2 and CH_4 emission, laying ducks emitted the highest at 5.333×10^{-3} time compere with the same weight of livestock animals. 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 laying duck had more contribution to the cause of global warming that each livestock.

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

Animal	C-input (kg.C/livestock animal/day)	C-input/same livestock animal (kg. C-input /kg livestock animal/day)	C-fixation (kg.C/ livestock animal/day)	C-fixation/ same livestock animal (kg. C-input /kg livestock animal /day)	C-emission (kg.C/ livestock animal /day)	C-emitted/ same livestock animal C-emission/kg livestock animal/day)	C-emission/C-input (%)	C-emission/ C-fixation (%)	Fixation effiedcy C = (C-input-C-emission)/ C-input (%)
Swine	0.942±0.04	$9.53x10^{-3}$	0.641±0.63	$6.48x10^{-3}$	0.275±0.58	$2.78x10^{-3}$	29.17	42.90	68.79
Goats	1.13±1.68	$30.66x10^{-3}$	0.713±1.14	$19.34x10^{-3}$	0.383±1.46	$10.40x10^{-3}$	33.92	53.77	63.09
three breed-cross native chicken	0.047±0.48	$39.83x10^{-3}$	0.031±0.49	$25.83x10^{-3}$	0.016±0.63	$13.33x10^{-3}$	33.48	51.61	64.85
pekin duck	0.114±0.57	$39.43x10^{-3}$	0.079±0.81	$26.46x10^{-3}$	0.035±0.79	$10.77x10^{-3}$	27.31	40.70	67.11
laying ducks	0.143±0.57	$85.63x10^{-3}$	0.094±1.18	$56.29x10^{-3}$	0.046±1.37	$27.54x10^{-3}$	32.17	48.92	65.74

Table 4.2 Rates of carbon input, carbon fixation and carbon emission of animals compere the same weight (mean ± S.D.).

Parameter	**Swine**	**Goat**	**Three cross breed native chicken**	**Pekin duck**	**Laying duck**
C-input (kg.C/livestock animal/day)	$9.53 x 10^{-3}$	$30.66 x 10^{-3}$	$39.83 x 10^{-3}$	$39.43 x 10^{-3}$	$85.63 x 10^{-3}$
C-fixation (kg.C/livestock animal/day)	$6.48 x 10^{-3}$	$19.34 x 10^{-3}$	$25.83 x 10^{-3}$	$26.46 x 10^{-3}$	$56.29 x 10^{-3}$
C-emission (kg.C/livestock animal/day)	$2.78 x 10^{-3}$	$10.40 x 10^{-3}$	$13.33 x 10^{-3}$	$10.77 x 10^{-3}$	$27.54 x 10^{-3}$
C-emission/C-input (%)	29.17	33.92	33.48	27.31	32.17
C-emission/C-fixation (%)	42.90	53.77	51.61	40.70	48.92
Fixation efficiency C = (C-input -C-emission)/- input (%)	68.79	63.09	64.85	67.11	65.74

Table 4.3 Carbon emission per individual per day and carbon emission per day comparing from same weight of animals (mean ± S.D.).

Animal	Fresh faeces wt (kg./livestock animal/day)	% Faeces per livestock wieght	Carbon emission (kg.C/ livestock animal/day)	Mean live animal weight in farm (kg./livestock animal)	Carbon emission from same weight (kg.C/ livestock animal/day) x10^{-3}	Mean weight of egg (kg/livestock animal /day)
Swine	1.34	1.35	0.275±0.58	98.94	3.75	N.A
Goats	1.38	3.74	0.383±1.46	36.86	38.86	N.A
Three breed-cross native chicken	0.029	2.46	0.016±0.63	1.18	39.32	N.A
Pekin ducks	0.102	3.14	0.035±0.79	3.25	33.82	N.A
Laying ducks	0.036	2.16	0.046±1.37	1.67	59.38	0.074±0.007

Note: N.A = Not available.

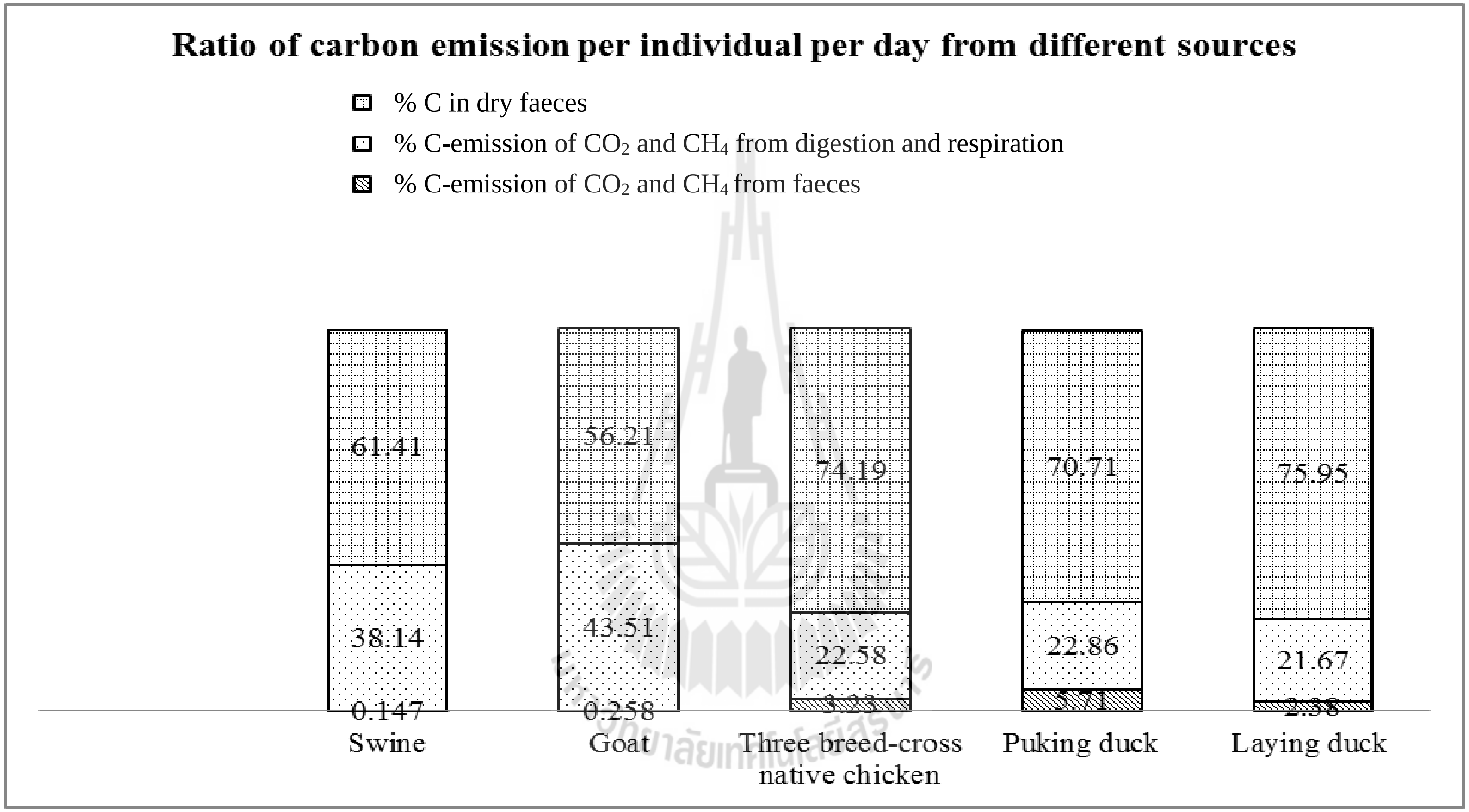


Figure 4.1 Ratio of carbon emission per individual per day from different sources of animals.

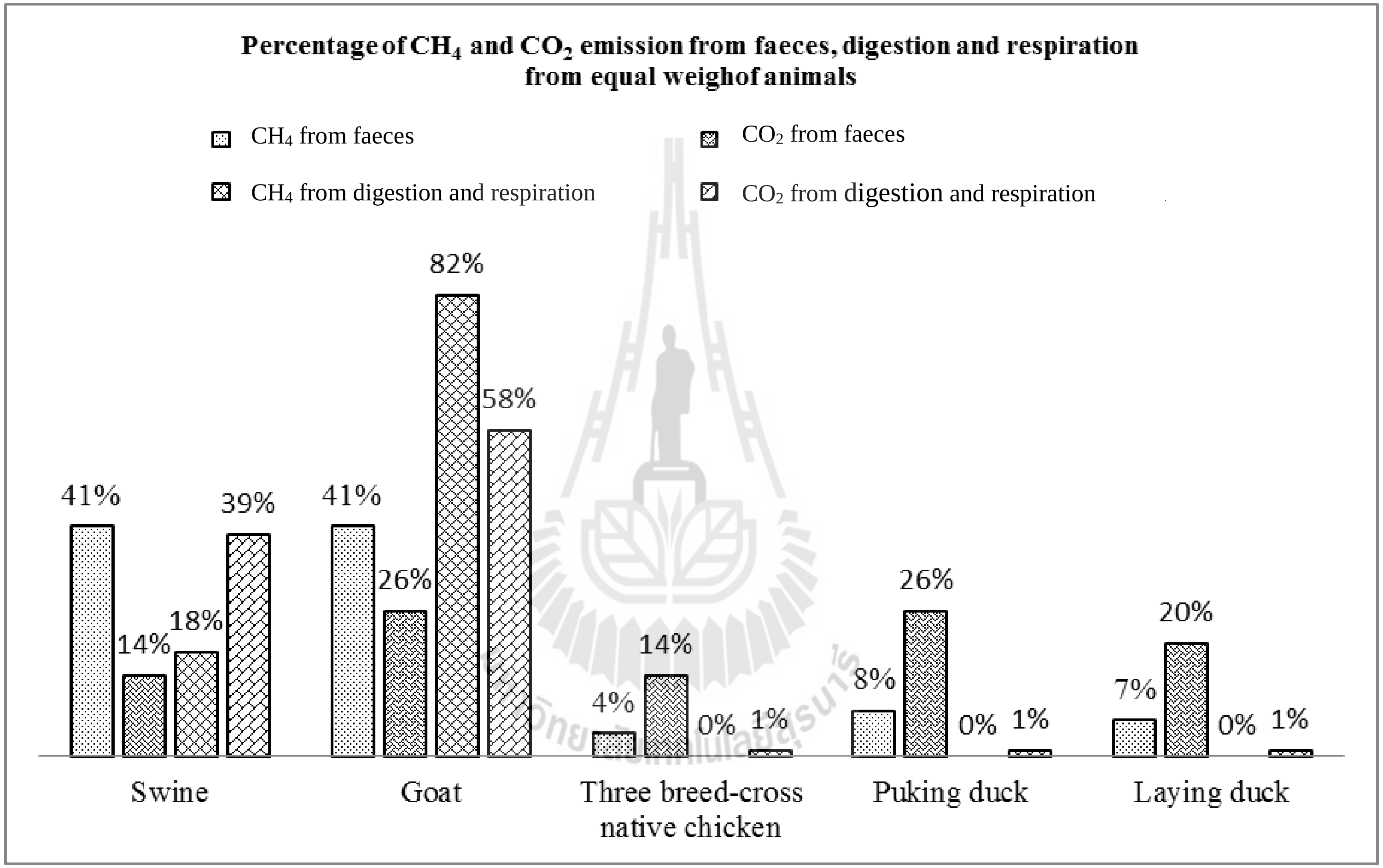


Figure 4.2 Percentage of CH_4 and CO_2 emission from faeces, digestion and respiration from same weight of animals.

Table 4.4 Gases from swine, goats, three breed-cross native chicken, pekin ducks and laying ducks in farms of Thailand (mean ± S.D.).

Animal	Mean of gas from	CH_4 (kg/livestock animal/day)	CO_2 (kg/livestock animal/day)	Ratio $CH_4 : CO_2$		$CH_4 : CO_2$ At same weight
Swine	Faeces	0.0001±0.0000	0.0010±0.0003	0.0072	Total 2 sources = 0.0283	2.860×10^{-4}
	Digestion and respiration	0.0071±0.0044	0.2536±0.1286	0.2546		
Goats	Faeces	0.0002±0.000002	0.0018±0.000156	0.0316	Total 2 sources = 0.0843	2.287×10^{-3}
	Digestion and respiration	0.0314±0.0063	0.3732±0.000213	0.3750		
Three breed-cross native chicken	Faeces	0.00001±0.0000	0.0010±0.0003	0.00001	Total 2 sources = 0.000897	7.605×10^{-4}
	Digestion and respiration	N.D.	0.00684±0.00054	0.0078		
Pekin ducks	Faeces	0.00002±0.000002	0.0018±0.000156	0.00002	Total 2 sources = 0.00215	6.615×10^{-4}
	Digestion and respiration	N.D.	0.0075±0.000213	0.0093		
Laying ducks	Faeces	0.000016±0.0000	0.0014±0.0003	0.000016	Total 2 sources = 0.00533	5.333×10^{-3}
	Digestion and respiration	N.D.	0.0071±0.1024	0.0030		

Source: Hartung (1992); Klwerenbeek (1988); Tamminga (1992).

The results of total carbon emission from each animal are shown in the Table 4.5. The UNECE (2004) explained the carbon emission by Mass Conservation Principle which could tell total carbon emission from animals per year for swine, goats, three breed-cross native chicken, pekin ducks and laying ducks correlated with the number of each livestock animal as follow:

$$C\text{-emission}_{livestock} = (0.10)\ \text{Swine} + (0.22)\ \text{Goat} + (0.006)\ \text{Three breed-cross native chicken} + (0.01)\ \text{Pekin duck} + (0.017)\ \text{Laying duck} \quad (4.1)$$

Where:

$C\text{-emission}_{livestock}$	=	total carbon emission from body of swine, goats, three breed-cross native chickens, pekin ducks and laying ducks (ton carbon per year.
Swine	=	number of swine (kg).
Goats	=	number of goats (kg).
Three breed-cross native chickens	=	number of three breed-cross native chickens (kg).
Pekin ducks	=	number of pekin ducks (kg).
Laying ducks	=	number of laying ducks (kg).

The study on the rate of carbon transfer from animal feed to each livestock animal by consumption (C_{-input}) and then fixed in livestock animal bodies, organs ($C_{-fixation}$), as well as, the carbon contents from animal faeces excreted and carbon in the forms of CO_2 and CH_4 from digestion and respiration of livestock animal ($C_{-emission}$) during rearing duration for livestock animal are shown in Table 4.5. The goats consume the roughage and low nutrient intake. The roughage in digestive system have fermentation by aerobic bacteria engender methane (CH_4) which the global warming potentials (GWP) of CH_4 is estimate to be 21 times that of CO_2. At same body weight of livestock animals, it can be ranked the carbon transfer (C_{-input}) from higher to lower as laying duck > three breed-cross native chicken > pekin duck > goat > swine. The relationship between carbon consumption (C_{-input}) and carbon emission from livestock animals ($C_{-emission}$) at a confidence level of 95% is illustrated in Figures 4.3 to 4.6.

Table 4.5 Average of carbon input (C_{-plant}) fixed in animals ($C_{-fixation}$) emitted from animals ($C_{-emission}$) in faeces ($C_{-output}$) and C-emitted of CO_2 and CH_4 from respiration and digestion (mean ± S.D.).

animal	Amount C transferred from plant food to animal (kg.C/kg.livestock animal/day)	Carbon fixatiom (kg.C/livestock animal/day)					Carbon emitted (kg.C/livestock animal/day)			
		Egg	Total C accumulatated in body (mass Equilibrium)	meat	intrails	Bone, skin, blood etc (mass Equilibrium)	Total C-emitted from animal	Dry faeces	C-emission of CO_2 and CH_4	
									faeces	Digestion and respiration
Swine	0.942±0.04	N.D.	0.641±0.63	0.046±2.83	0.008±0.81	0.628	0.301±0.06	0.207±0.04	0.0005±0.15	0.094±0.34
Goats	1.13±1.68	N.D.	0.713±1.14	0.044±1.64	0.0093±0.93	0.66	0.597±1.46	0.305±1.33	0.0008±0.03	0.292±0.06
Three breed-cross 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
Pekin ducks	0.114±0.57	N.D.	0.086±0.81	0.006±1.94	0.0009±1.43	0.079	0.028±0.86	0.019±0.18	0.0004±0.45	0.0086±0.03
Laying ducks	0.143±0.57	0.044±007	0.094±1.18	0.006±0.72	0.009±2.75	0.044	0.049±1.97	0.034±0.92	0.0003±0.58	0.015±0.74

Note: N.D. = not defection.

The results of regression analysis can be summarized the relationship between C-emission and C-input of swine, goats, three breed-cross native chicken, pekin ducks and laying ducks in the regression equations of 4.2, 4.3, 4.4, 4.5 and 4.6

$$\text{C-emission}_{\text{swine}} = 0.082\ (\text{C-input}_{\text{swine feed}}) - 0.137 \qquad R^2 = 0.93 \qquad (4.2)$$

Where:

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

$\text{C-input}_{\text{Swine feed}}$ = carbon content in feed which transferred to swine by consumption at pork duration or average age of 135.24±2.604 days with average value at 0.942±0.04 (kg.C/swine/day)

$$\text{C-emission}_{\text{goat}} = 0.340\ (\text{C-input}_{\text{goat feed}}) + 0.139 \qquad R^2 = 0.89 \qquad (4.3)$$

Where:

$\text{C-emission}_{\text{goat}}$ = carbon emitted from goats (kg.C/goat/day)

$\text{C-input}_{\text{goat feed}}$ = carbon content in feed which transferred to goats by consumption at goat meat duration or average age of 120.47±0.48 days with average value at 1.13±1.68 (kg. C/goat/day)

$$\text{C-emission}_{\text{three breed-cross native chicken}} = 0.353\ (\text{C-input}_{\text{three breed-cross native chicken feed}}) + 0.061 \qquad R^2 = 0.96 \qquad (4.4)$$

Where:

$C\text{-emission}_{\text{three breed-cross native chicken}}$

= carbon emitted from three breed-cross native chicken (kg.C/three breed-cross native chicken/day)

$C\text{-input}_{\text{three breed-cross native chicken feed}}$

= carbon content in feed which transferred to three breed-cross native chicken by consumption at three breed-cross native chicken meat duration or average age of 56.63±1.72 days with average value at 0.047±0.048 (kg.C/three breed-cross native chicken/day)

$$C\text{-emission}_{\text{pekin duck}} = 0.429\ (C\text{-input}_{\text{Pekin duck feed}}) + 0.089 \qquad R^2 = 0.94 \quad (4.5)$$

Where:

$C\text{-emission}_{\text{pekin duck}}$ = carbon emitted from pekin ducks (kg.C/pekin duck /day)

$C\text{-input}_{\text{pekin duck feed}}$ = carbon content in feed which transferred to pekin ducks by consumption at goat meat duration or average age of 42.47±0.48 days with average value at 0.114±0.57 (kg.C/pekin duck/day)

$$C\text{-emission}_{\text{laying duck}} = 0.327\ (C\text{-input}_{\text{laying feed}}) + 0.057 \qquad R^2 = 0.87 \quad (4.6)$$

Where:

$C\text{-emission}_{\text{laying duck}}$ = carbon emitted from laying ducks (kg.C/laying duck day)

C-input $_{laying\ duck}$ = carbon content in feed which transferred to laying ducks by consumption at goat meat duration or average age of 435.47±60.48 days with average value at 0.143±0.57 (kg.C/laying duck/day)

The comparison of the percent of average carbons which were fixed in studied animals and eggs per average carbon content in animal feed for each livestock animal per day ($C_{fixation}/C_{input}$) found that swine fixed the highest (68.79%) carbon from animal feed (Table 4.6).

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

Animal	**Total meat (%)**	**Total entrail (%)**	**Skin, blood, bone, head, ect. %**	**Cfixation /Cinput%**
Swine	46.23±2.83	7.89±0.81	45.88±0.96	68.79
Goats	43.66±1.64	9.27±0.93	48.67±1.67	63.09
Three breed-cross native chicken	49.11±0.89	11.37±1.14	39.52±1.75	64.85
Pekin ducks	47.06±1.94	10.46±1.43	42.48±1.63	67.11

The results of the fixation rates from animal feed to livestock animals by consumption in raising durations and the Principle of Mass Conservation (UNECE, 2004) can be shown the carbon input and carbon fixation from each livestock animal as follow:

$C_{\text{-input}}$ = (0.344) Swine + (0.412) Goat + (0.017) Three breed-cross native chicken + (0.042) Pekin duck + (0.052) Laying duck (4.7)

$C_{\text{-fixation}}$ = (0.234) Swine + (0.260) Goat + (0.011) Three breed-cross native chicken + (0.031) Pekin duck + (0.034) Laying duck (4.8)

Where:

$C_{\text{-input}}$	= carbon mass emission from animal feed to livestock animals by consumption of each livestock animal in utilized age (ton carbon per year).
$C_{\text{-fixation}}$	= carbon fixation in each animal body included eggs (ton carbon per year).
Swine	= number of swine (kg).
Goat	= number of goats (kg).
Three breed-cross native chicken	= number of three breed-cross native chickens (kg).
Pekin duck	= number of pekin ducks (kg).
Laying duck	= number of laying ducks (kg).

Concurrently, considering the relationships between carbon input to livestock animal by feed consumption and carbon fixation in each livestock animal which can be shown in the formulas 4.9 to 4.13 by analysis of the relationships of each livestock animal at 95% confidence ($p \leq 0.05$).

$$\text{C-fixation}_{swine} = 0.782\,(\text{C-input}_{swine\ feed}) + 0.276 \qquad R^2 = 0.98 \qquad (4.9)$$

Where:

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

$\text{C-input}_{swine\ feed}$ = carbon content in feed which transferred to swine by consumption at pork duration or average age of 135.24±2.604 days with average value at 0.942±0.04 kg.C/swine/day)

$$\text{C-fixation}_{goat} = 0.806\,(\text{C-input}_{goat\ feed}) + 1.143 \qquad R^2 = 0.89 \qquad (4.10)$$

Where:

C-fixation_{goat} = carbon fixation from goats (kg.C/goat/day)

$\text{C-input}_{goat\ feed}$ = carbon content in feed which transferred to goat by consumption at goat meat duration or average age of 120.47±0.48 days with average value at 1.13±1.68 (kg.C/goat/day)

$$\text{C-fixation}_{three\ breed\text{-}cross\ native\ chicken} = 0.760\,(\text{C-input}_{Three\ breed\text{-}cross\ native\ chicken\ feed}) + 0.049 \qquad R^2 = 0.91 \qquad (4.11)$$

Where:

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

C-input $_{\text{three breed-cross native chicken feed}}$

= carbon content in feed which transferred to three breed-cross native chicken by consumption at three breed-cross native chicken meat duration or average age of 56.63±1.72 days with average value at 0.047±0.048 (kg.C/Three breed-cross native chicken/day)

$$\text{C-fixation}_{\text{pekin duck}} = 0.754\ (\text{C-input}_{\text{Pekin duck feed}}) + 0.372 \quad R^2 = 0.89 \quad (4.12)$$

Where:

C-fixation$_{\text{pekin duck}}$ = carbon fixation from pekin duck (kg.C/pekin duck/day)

C-input$_{\text{pekin duck feed}}$ = carbon content in feed which transferred to pekin duck by consumption at goat meat duration or average age of 42.47±0.48 days with average value at 0.114±0.57 (kg.C/pekin duck/day)

$$\text{C-fixation}_{\text{laying duck}} = 0.643\ (\text{C-input}_{\text{laying duck feed}}) + 0.257 \quad R^2 = 0.97 \quad (4.13)$$

Where:

C-fixation$_{\text{laying duck}}$ = carbon fixation from laying duck (kg.C/laying duck/day)

C-input$_{\text{laying duck feed}}$ = carbon content in feed which transferred to laying duck by consumption at goat meat duration or average age of 435.47±60.48 days with average value at 0.143±0.57 (kg.C/laying duck/day)

Moreover, the proportion of carbon contents from animal feed which were transferred to each livestock animal and fixed into parts of livestock animal bodies and faeces including carbon in the form of CO_2, CH_4 from digestion and respiration per livestock animal per day were also analyzed. Carbon content at 100 parts in animal feed, were fixed in bodies of pekin ducks, swine, three breed-cross native chicken, laying ducks and goats at 75.44%, 68.05%, 66.00%, 65.73% and 63.10%, respectively. The rest of carbon contents were released from each kind of livestock animals through the excretion of waste, respiration and digestion at 24.56%, 31.95%, 34.00%, 34.27% and 36.90%, respectively. These carbons are an important part in causing the environmental problems. The result showed that pekin ducks fixed the most carbon in their bodies and released lowest carbon compere to other animals. Even though, the pekin ducks had the most of percent carbon which was fixed in body but swine had the highest carbon fixation efficiency (68.79%) followed by pekin ducks (67.11%), laying ducks (65.54%), three breed-cross native chicken (64.55%) and goats (63.09%), respectively. The results are illustrated in Figures 4.3 to 4.7.

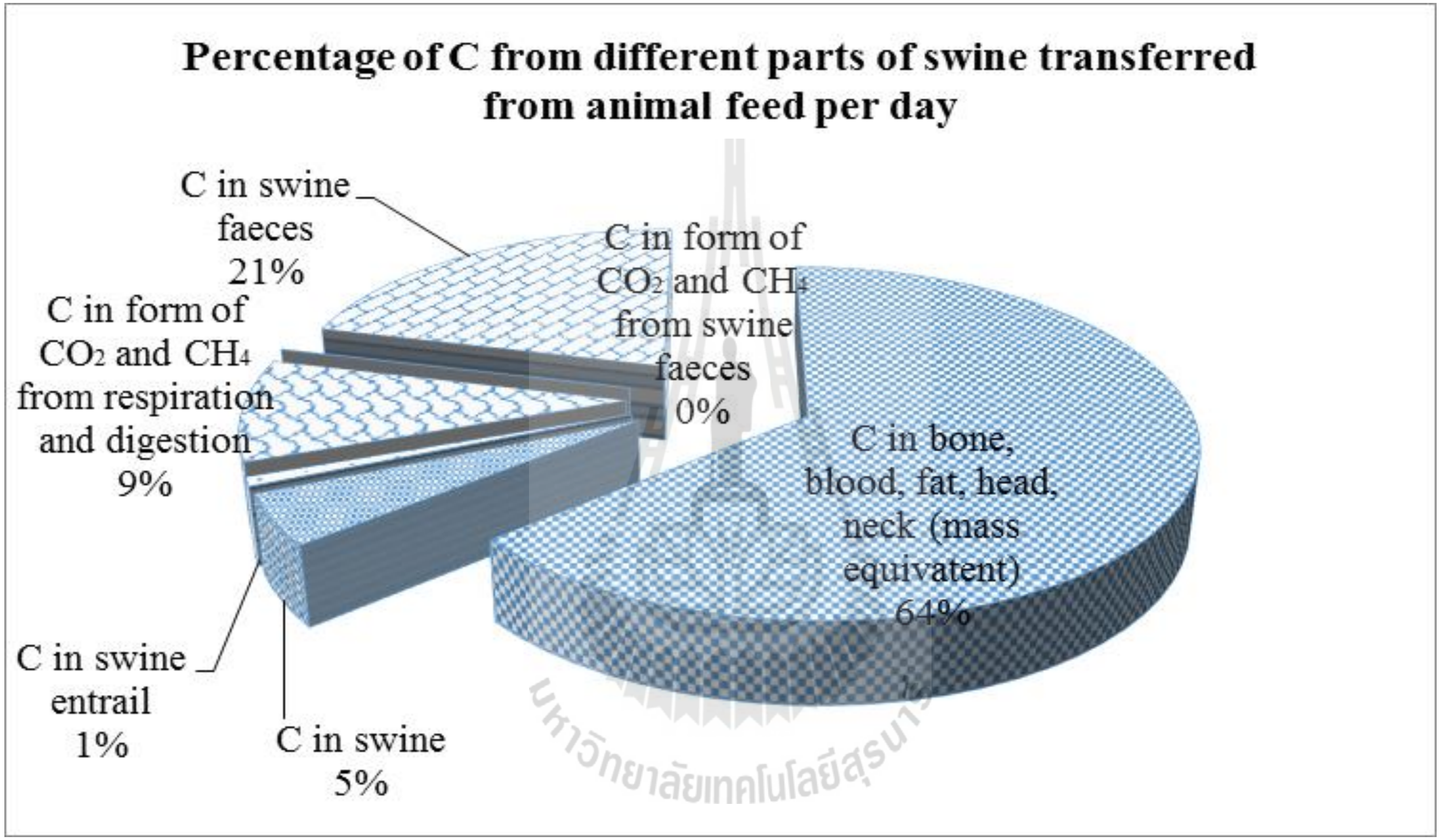


Figure 4.3 Percentage of C from different parts of swine transferred from animal feed per day.

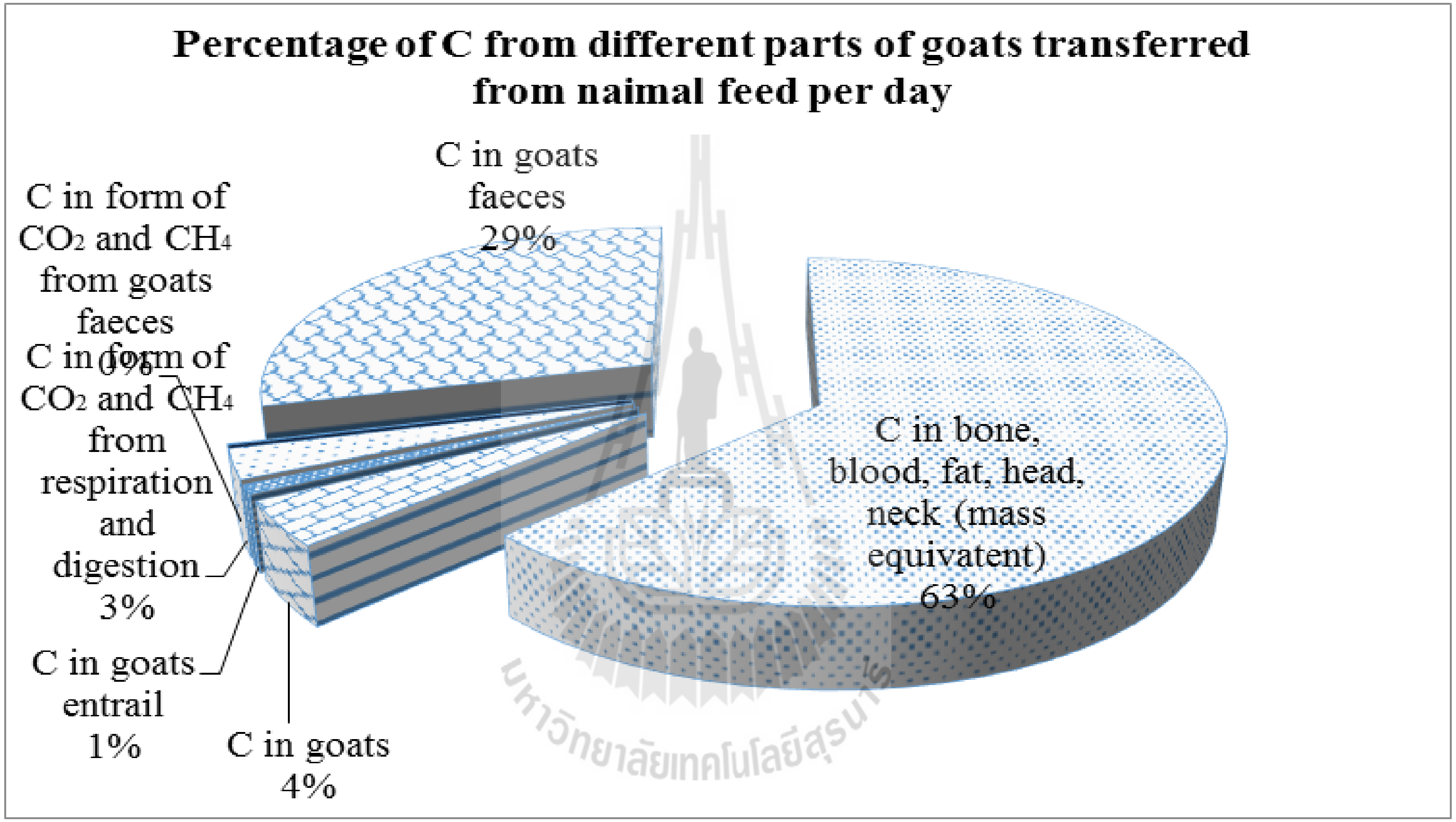


Figure 4.4 Percentage of C from different parts of goats transferred from animal feed per day.

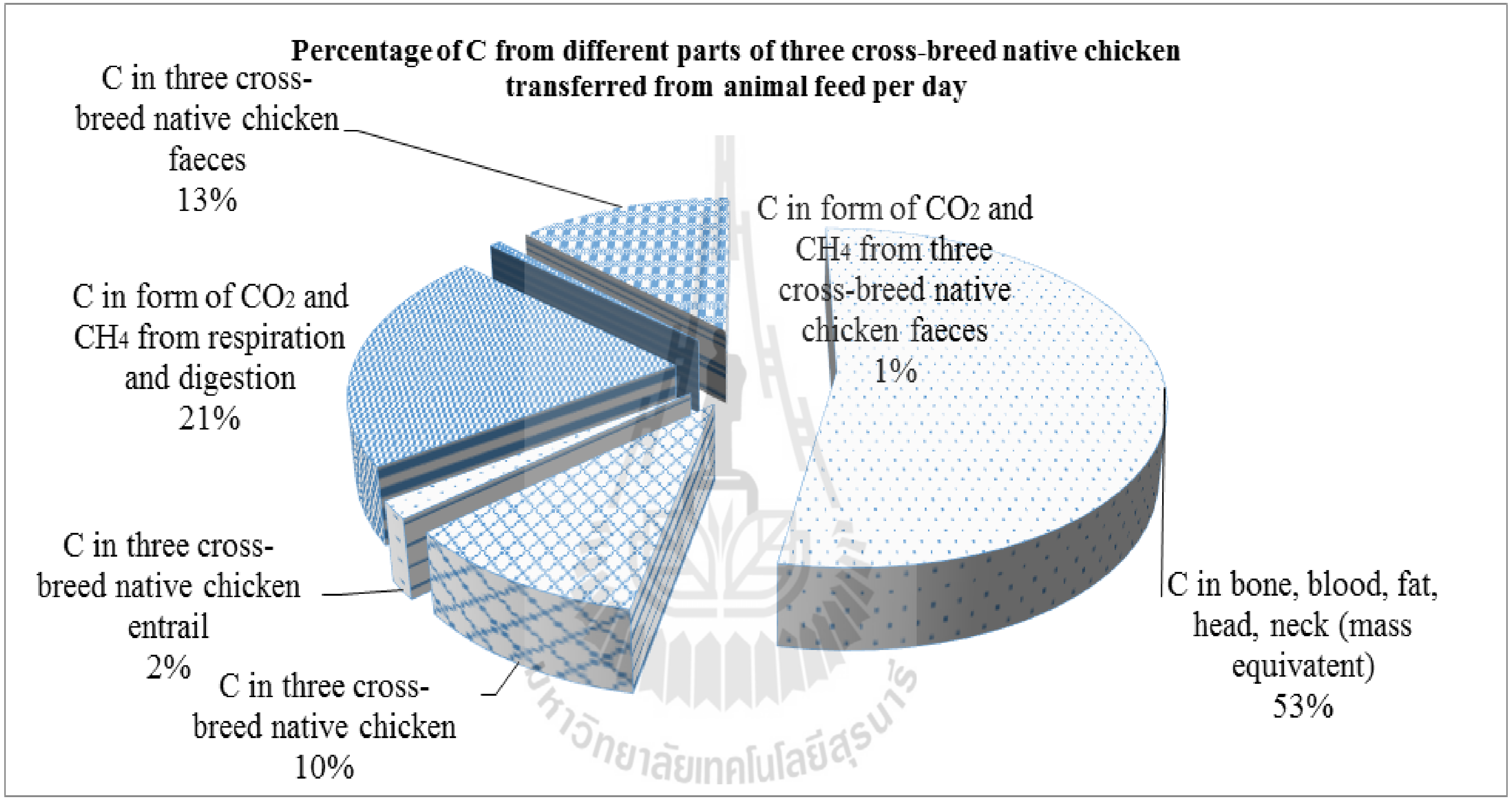


Figure 4.5 Percentage of C from different parts of three breed-cross native chicken transferred from animal feed per day.

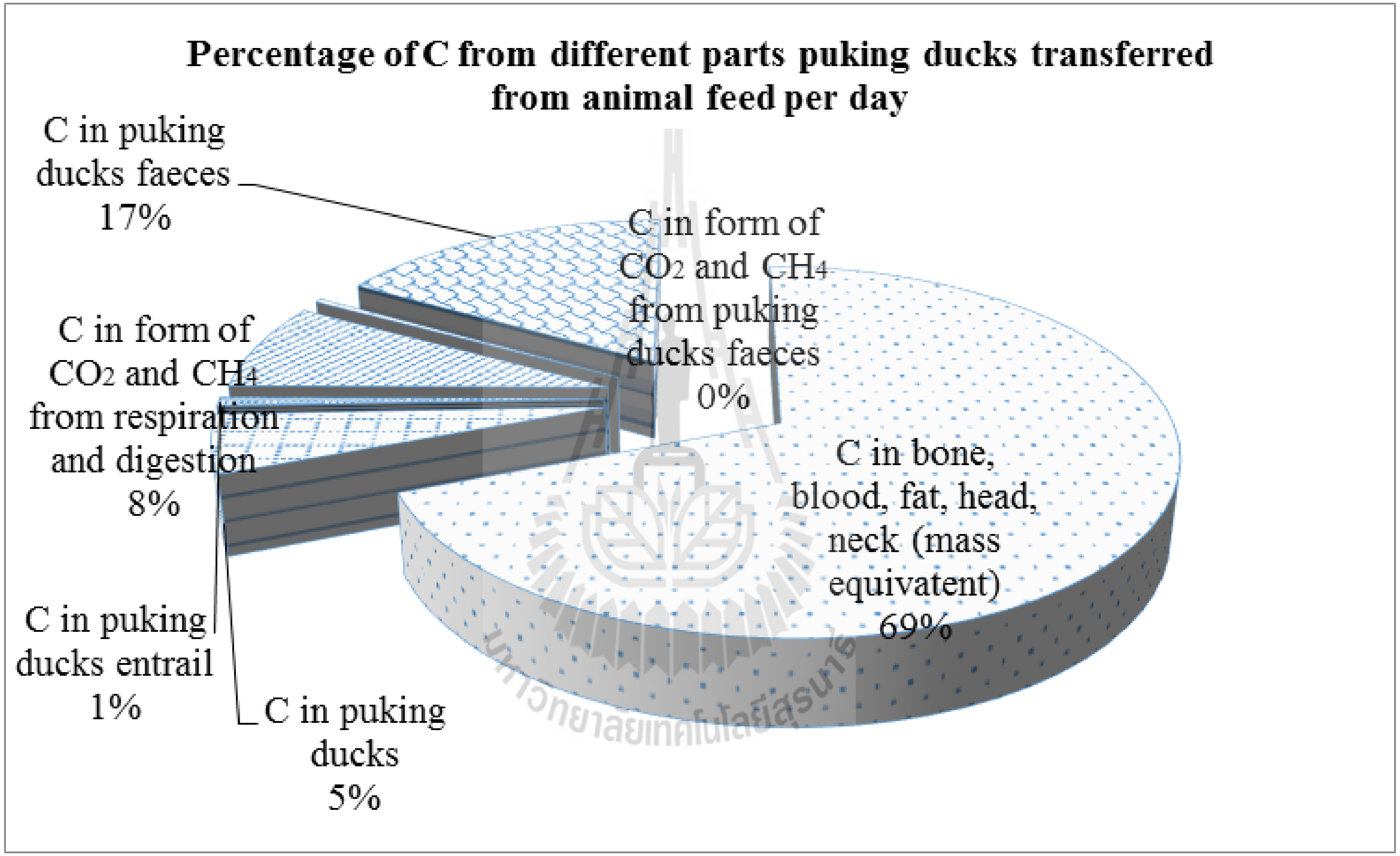


Figure 4.6 Percentage of C from different parts of pekin ducks transferred from animal feed per day.

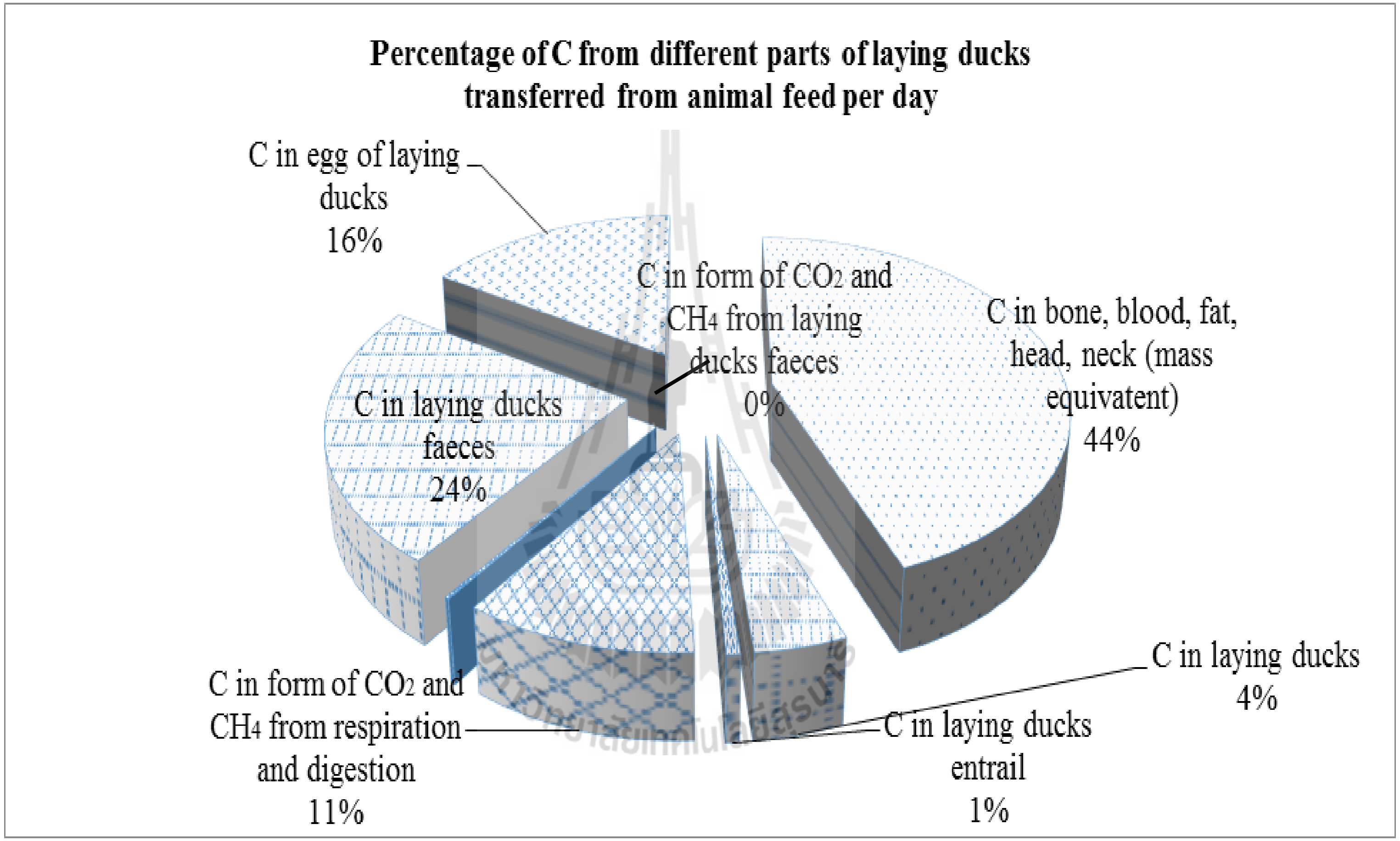


Figure 4.7 Percentage of C from different parts of laying ducks transferred from animal feed per day.

4.1.2 Carbon fixation and carbon emission in each livestock in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces

4.1.2.1 Carbon massflow of swine in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces

The carbon contents in the unit of kg carbon per kg livestock production per day (kg.C/kg.livestock animal/day) were used to study the comparison of carbon massflow from animal feed for feeding to biomass for different livestock animal (C-input), the carbon mass which was fixed in the livestock animal bodies (C-fixation) and the carbon emitted in the forms of CO_2 and CH_4 from faeces, digestion and respiration (C-emission) in Nakhon Ratchasima Chon Buri and Prachin Buri provinces, Thailand were studied.

The results found that carbon massflow from animal feed for feeding of swine ($C\text{-}_{input}$) in Chon Buri province had the highest value at 9.750×10^{-3} kg.C/kg.swine/day, whereas in Prachin Buri province had carbon input at 9.526×10^{-3} kg.C/kg.swine/day but the lowest in Nakhon Ratchasima province at 9.424×10^{-3} kg.C/kg.swine/day. In addition, the rate of carbon input from animal feed by consumption including carbon fixation in livestock bodies ($C\text{-}_{fixation}$) in Chon Buri province had the highest value at 9.066×10^{-3} followed by in Prachin Buri province at 6.861×10^{-3} and Nakhon Ratchasima province at 6.845×10^{-3} kg.C/kg.swine/day, respectively.

Moreover, the carbon emission from enteric fermentation, faeces and respiration ($C\text{-}_{emission}$) in Chon Buri province had the highest carbon emission at 2.687×10^{-3} kg.C/kg.swine/day. While Prachin Buri province had the carbon emission at 2.665×10^{-3} kg.C/kg.swine/day and Nakhon Ratchasima province had the lowest carbon emission at 2.579×10^{-3} kg.C/kg.swine/day. This probably because of the different farm management and the system of farms which could be close system or open system.

Furthermore, the carbon emission from energy used in farms and slaughterhouses were also important. The study found that in Nakhon Ratchasima province had the highest value at 32.426×10^{-3} kg.C/kg.swine/day. In Prachin Buri province had carbon emission at 32.296×10^{-3} kg.C/kg.swine/day and Chon Buri province had the lowest carbon emission value at 31.829×10^{-3} kg.C/kg.swine/day. This due to the distance from animal feed factories to farms, parent stock farms to farms, farms to slaughterhouses and slaughterhouses to markets as shown in Tables 4.7 to 4.8 and Figure 4.8.

According to the carbon emission from pork production the result showed that the comparison of carbon fixation efficiency $[(C_{-input} - C_{-emission})/C_{-input}]$ of pork production was higher in Nakhon Ratchasima than in Chon Buri and Prachin Buri provinces which were 72.63%, 72.44% and 72.02%, respectively. This is another reason to support that pork productions in Nakhon Ratchasima province create the lowest environmental impacts as shown in Table 4.7.

Table 4.7 Rates of carbon input, carbon fixation and carbon emission of swine compere the same weight in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (mean ± S.D.).

Animal	Mean live animal weight in farm (kg./ind)	C-input (kg.C/livestock animal/day)	C-input/same livestock animal (kg. C-input/kg livestock animal/day)	C-fixation (kg.C/ livestock animal/day)	C-fixation/ same livestock animal (kg. C-input /kg livestock animal/day)	C-emission (kg.C/ livestock animal/day)	C-emitted/ same livestock animal C-emission/kg livestock animal/day)	C-emission/ C- input (%)	C-emission/ C-fixation (%)	Fixation effiedcy C = (C-input - C-emission)/C-input (%)
Nakhon Ratchasima	99.64	0.939±0.04	9.424×10^{-3}	0.682±0.07	6.845×10^{-3}	0.257±0.16	2.579×10^{-3}	27.37	37.68	72.63
Chon Buri	97.13	0.947±0.08	9.750×10^{-3}	0.686±0.63	7.066×10^{-3}	0.261±0.08	2.687×10^{-3}	27.56	38.06	72.44
Prachin Buri	98.68	0.940±0.01	9.5261×10^{-3}	0.677±0.09	6.861×10^{-3}	0.263±0.51	2.665×10^{-3}	27.98	38.85	72.02

Table 4.8 Average of C-emission from energy in farm and slaughterhouse of swine in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (mean ± S.D.).

Average C from energy		C-emission (kg.C/livestock animal/day)		
		Nakhon Ratchasima	**Chon Buri**	**Prachin Buri**
Farm	Electricity *	0.02±0.003	0.02±0.004	0.019±0.05
	Fuel for transpotation **	0.79±0.95	0.83±0.15	0.81±0.85
	Fuel for machine*** or LPG****	N.D.	N.D.	N.D.
	Total C from energy/ kg.livestock animal /day	0.81	0.85	0.829
	Total for energy/livestock animal/day	8.129×10^{-3}	8.751×10^{-3}	8.400×10^{-3}
Slaughterhouse	Electricity *	0.051±0.04	0.48±0.07	0.051±0.13
	Fuel for transpotation **	0.01±0.00	0.009±0.00	0.011±0.00
	Wood chaff LPG****	2.36±1.07	2.23±0.02	2.25±1.02
	Total C from energy/ kg.livestock animal /day	2.421	2.287	2.312
	Total for energy/livestock anima/day	24.297×10^{-3}	23.457×10^{-3}	23.429×10^{-3}
Total $C_{emission}$ from energy of two source	**kg.C/ kg.livestock animal /day**	**3.17**	**3.137**	**3.141**
	kg.C/ livestock animal /day	**32.426×10^{-3}**	**32.296×10^{-3}**	**31.829×10^{-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_2/1 kg.LPG 0r 0.848 kg.C/1 kg.LPG. N.D. = not defection

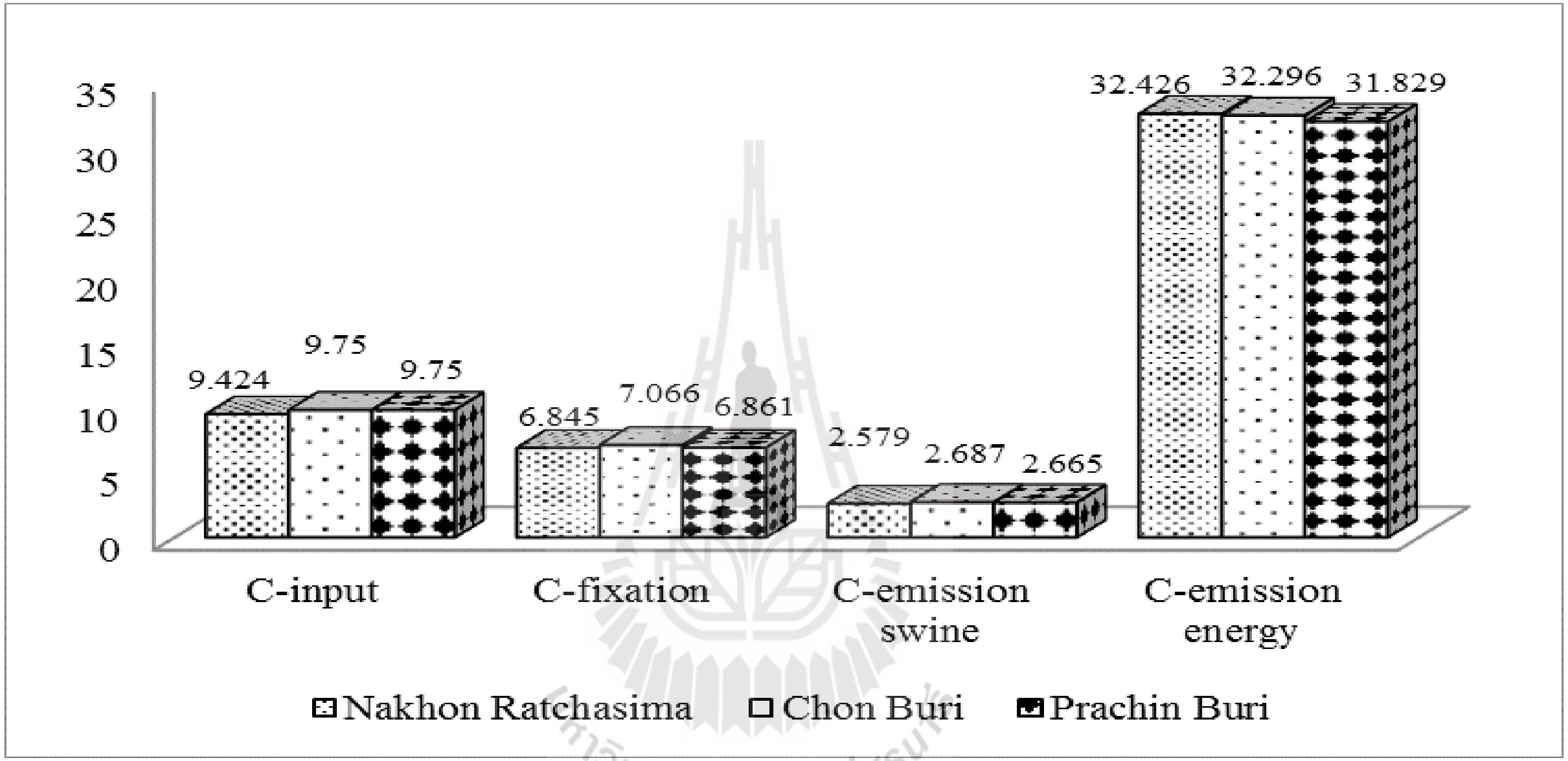


Figure 4.8 Carbon massflow of swine production in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces Thailand.

4.1.2.2 Carbon massflow of goats in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces

The carbon contents in the unit of kg carbon per kg livestock production per day (kg.C/kg.livestock animal/day) were used to study the comparison of carbon massflow from animal feed for feeding to biomass for different goat (C-input), the carbon mass which was fixed in the livestock animal bodies (C-fixation) and the carbon emitted in the forms of CO_2 and CH_4 from faeces, digestion and respiration (C-emission) in Nakhon Ratchasima Chon Buri and Prachin Buri provinces Thailand.

The result found that carbon massflow from animal feed for feeding of goats (C_{input}) in Nakhon Ratchasima province had the highest value at $34.406x10^{-3}$ while in Prachin Buri province had carbon input at $29.919x10^{-3}$ and in Chon Buri province had the lowest carbon input at $28.769x10^{-3}$ kg.C/kg.goat/day. In addition, the rate of carbon input from animal feed by consumption including carbon fixation in livestock bodies ($C_{fixation}$) in Nakhon Ratchasima, had the hightes value at $24.396x10^{-3}$ followed by Prachin Buri and Chon Buri provinces at $18.108x10^{-3}$ and $17.262x10^{-3}$ kg.C/kg.goat/day, respectively.

Moreover, the carbon emission from enteric fermentation, faeces and respiration ($C_{emission}$) in Prachin Buri province had the highest value at $10.811x10^{-3}$ kg.C/kg.goat/day. While in Chon Buri province had the value at $10.594x10^{-3}$ kg.C/kg.goat/day but Nakhon Ratchasima province had the lowest carbon emission at $9.579x10^{-3}$ kg.C/kg.goat/day.

In addition, the carbon emission from energy used in farms and slaughterhouses were important. The result found that in Nakhon Ratchasima province had the highest value at 68.008×10^{-3} kg.C/kg.goat/day. While, in Chon Buri and Prachin Buri provinces has carbon emission similarly value at 60.229×10^{-3} and 60.838×10^{-3} kg.C/kg.goat/day. The goat farms in each province had high carbon emission from the use of energy because of the long distance from animal feed factories to farms, farms to slaughterhouses or market and the food plant to farms. Moreover, the goats were transported to the three southern border province of Thailand and the goats desire the fresh food plants and the farmers had to provide food plants to goat every day as shown in Tables 4.9 to 4.10 and Figure 4.9.

In accordance with the carbon emission from goat meat production the result showed that the performance comparison of carbon fixation efficiency $[(C_{-input} - C_{-emission}) / C_{-input}]$ of goat meat production in three provinces were Nakhon Ratchasima > Chon Buri > Prachin Buri provinces at 71.53%, 63.33% and 62.62%, respectively. This is another reason to support that goat meat production in Nakhon Ratchasima province create the lowest environmental impacts as shown in Table 4.9.

Table 4.9 Rates of carbon input, carbon fixation and carbon emission of goats compere the same weight in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (mean ± S.D.).

Animal	Mean live animal weight in farm (kg./ind)	C-input (kg.C/livestock animal/day)	C-input/same livestock animal (kg. C-input/kg. livestock animal /day)	C-fixation (kg.C/ livestock animal/day)	C-fixation/same livestock animal (kg. C-input /kg. livestock animal/day)	C-emission (kg.C/ livestock animal/day)	C-emitted/ same livestock animal C-emission/kg. livestock animal/day)	C- emission/ C- input (%)	C- emission/ C- fixation (%)	Fixation effiedcy C = (C-input – C-emission)/ C-input (%)
Nakhon Ratchasima	36.00	1.24±1.63	34.406×10^{-3}	0.887±1.08	24.639×10^{-3}	0.353±1.46	9.759×10^{-3}	28.47	39.80	71.53
Chon Buri	37.54	1.08±0.97	28.769×10^{-3}	0.684±1.26	17.262×10^{-3}	0.396±1.01	10.594×10^{-3}	36.67	57.89	63.33
Prachin Buri	37.00	1.07±1.49	29.919×10^{-3}	0.670±0.99	18.108×10^{-3}	0.400±1.27	10.811×10^{-3}	36.13	59.70	62.62

Table 4.10 Average of C-emission from energy in farm and slaughterhouse of goats in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (mean±S.D.).

Average C from energy		C-emission (kg.C/livestock animal/day)		
		Nakhon Ratchasima	**Chon Buri**	**Prachin Buri**
Farm	Electricity *	0.002±0.01	0.002±0.00	0.002±0.04
	Fuel for transpotation **	2.06±0.03	1.88±0.16	1.185±0.07
	Fuel for machine *** or LPG ****	N.D.	N.D.	N.D.
	Total C from energy/kg.livestock animal/day	2.062	1.882	1.852
	Total for energy/livestock animal/day	57.214×10^{-3}	50.133×10^{-3}	50.054×10^{-3}
Slaughterhouse	Electricity *	0.009±0.004	0.009±0.013	0.009±0.009
	Fuel for transpotation **	0.38±0.0016	0.37±0.024	0.39±0.114
	Wood chaff LPG ****	N.D.	N.D.	N.D.
	Total C from energy/kg.livestock animal/day	0.389	0.379	0.399
	Total for energy/livestock anima/day	10.894×10^{-3}	10.096×10^{-3}	10.784×10^{-3}
Total $C_{emission}$ from energy of two source	**kg.C/kg.livestock animal/day**	**2.451**	**2.261**	**2.251**
	kg.C/livestock animal/day	**68.008×10^{-3}**	**60.229×10^{-3}**	**60.838×10^{-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_2/1 kg.LPG 0r 0.848 kg.C/1 kg.LPG. N.D. = not defection

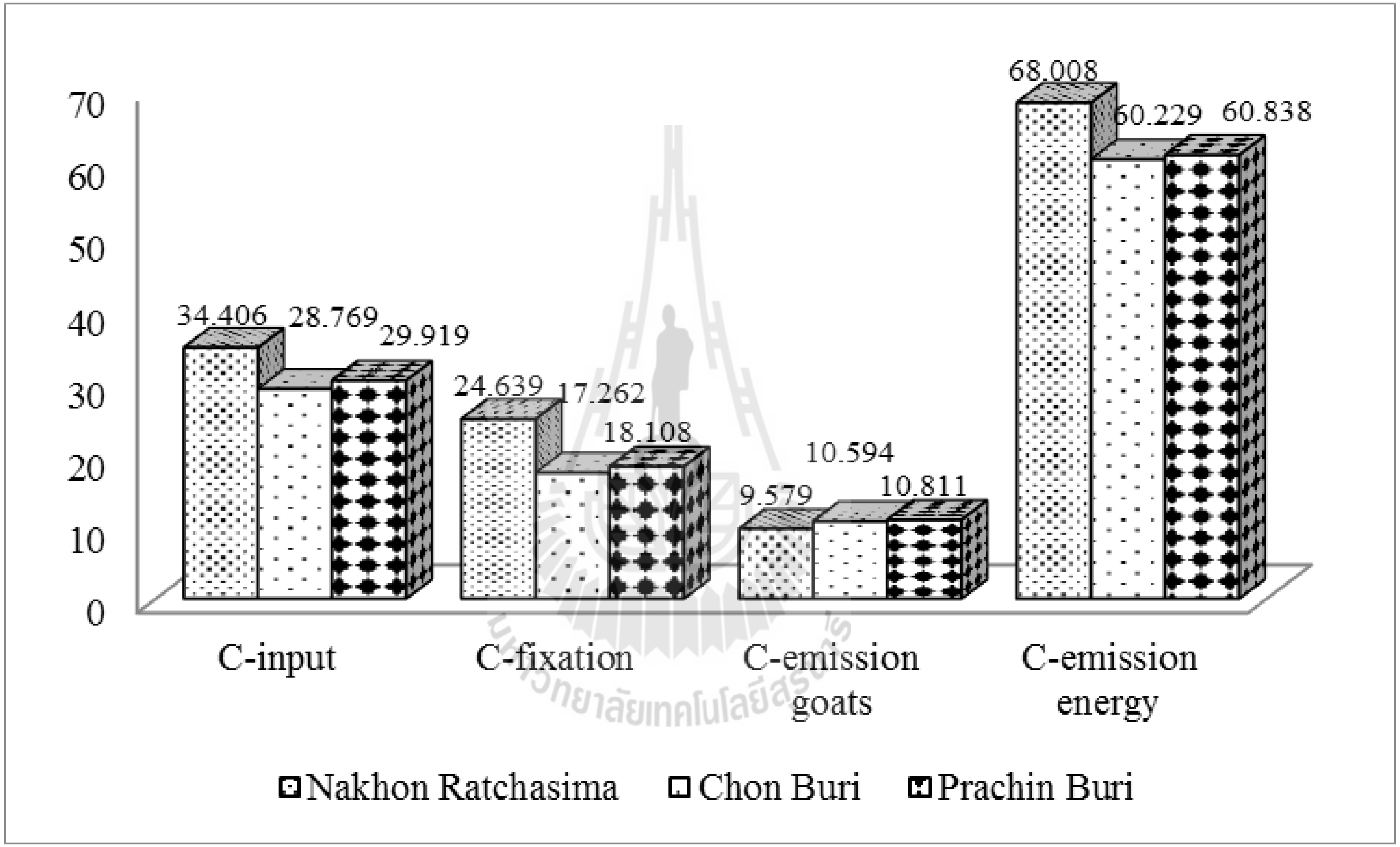


Figure 4.9 Carbon massflow of goat production in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces Thailand.

4.1.2.3 Carbon massflow of three breed-cross native chicken in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces

The carbon contents in the unit of kg carbon per kg livestock production per day (kg.C/kg.livestock animal/day) were used to study the comparison of carbon massflow from animal feed for feeding to biomass for different three breed-cross native chicken (C-input), the carbon mass which was fixed in the livestock animal bodies (C-fixation) and the carbon emitted in the forms of CO_2 and CH_4 from faeces, digestion and respiration (C-emission) in Nakhon Ratchasima Chon Buri and Prachin Buri provinces Thailand were studied.

The results found that carbon massflow from animal feed for feeding of three breed-cross native chicken ($C\text{-}_{input}$) in Prachin Buri province had the highest value at 43.592×10^{-3} kg.C/kg.three breed-cross native chicken/day. On the other hand in Nakhon Ratchasima province had carbon input at 33.330×10^{-3} kg.C/kg.three breed-cross native chicken/day and the lowest in Chon Buri province at 42.981×10^{-3} kg.C/kg.three breed-cross native chicken/day.

Additionally, the rate of carbon input from animal feed by consumption including carbon fixation in livestock bodies ($C\text{-}_{fixation}$) in Chon Buri province had the highest value at 28.947×10^{-3} followed by in Prachin Buri province at 28.205×10^{-3} and Nakhon Ratchasima province at 21.951×10^{-3} kg.C/kg.three breed-cross native chicken/day.

Besides, the carbon emission from enteric fermentation, faeces and respiration ($C\text{-}_{emission}$) in Prachin Buri province had the highest carbon emission at 15.385×10^{-3} kg.C/kg.three breed-cross native chicken/day. However, Chon Buri province had the carbon emission at 14.305×10^{-3} kg.C/kg.three breed-cross native chicken/day and Nakhon Ratchasima province had the lowest carbon emission at 11.328×10^{-3} kg.C/kg.three breed-cross native chicken/day.

Furthermore, the carbon emission from the use of energy in farms and slaughterhouses were also important. The study found that in Chon Buri province had the highest value at 63.248×10^{-3} kg.C/kg.three breed-cross native chicken/day. In Prachin Buri province had carbon emission at 61.404×10^{-3} kg.C/kg.three breed-cross native chicken/day, while Nakhon Ratchasima province had the lowest carbon emission value at 57.723×10^{-3} kg.C/kg.three breed-cross native chicken/day. This due to the distance from animal feed factories to farms, hatcheries to farms, farms to slaughterhouses and slaughterhouses to markets. The results are shown in Tables 4.11 to 4.12 and Figure 4.10.

In view of the carbon emission from three breed-cross native chicken meat productions, the results showed that the performance comparison of carbon fixation efficiency $[(C_{\text{-input}} - C_{\text{-emission}}) / C_{\text{-input}}]$ of three breed-cross native chicken meat productions in three provinces were Chon Buri > Nakhon Ratchasima > Prachin Buri provinces at 67.53%, 65.85% and 64.71%, respectively. This is another reason to support that three breed-cross native chicken meat productions in Chon Buri province create the lowest environmental impacts as shown in Table 4.11.

Table 4.11 Rates of carbon input, carbon fixation and carbon emission of three breed-cross native chicken compere the same weight in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (mean ± S.D.).

Animal	**Mean live animal weight in farm (kg./ind)**	**C-input (kg.C/livestock animal/day)**	**C-input/same livestock animal (kg. C-input/kg livestock animal /day)**	**C-fixation (kg.C/livestock animal/day)**	**C-fixation/ same livestock animal (kg. C-input/kg livestock animal /day)**	**C-emission (kg.C/ livestock animal/day)**	**C-emitted/same livestock animal C-emision/kg livestock animal /day)**	**C-emission/ C- input (%)**	**C-emission/ C- fixation (%)**	**Fixation effiedcy C = (C-input – C-emission)/ C-input (%)**
Nakhon Ratchasima	1.23	0.041±039	33.330×10^{-3}	0.027±0.48	21.951×10^{-3}	0.014±0.61	11.382×10^{-3}	34.15	51.85	65.85
Chon Buri	1.14	0.049±0.51	42.981×10^{-3}	0.033±0.51	28.947×10^{-3}	0.016±0.65	14.035×10^{-3}	32.65	48.48	67.35
Prachin Buri	1.17	0.051±0.53	43.592×10^{-3}	0.033±0.47	28.205×10^{-3}	0.018±0.49	15.385×10^{-3}	35.29	54.55	64.71

Table 4.12 Average of C-emission from energy in farm and slaughterhouse of three breed-cross native chicken in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (mean±S.D.).

Average C from energy		C-emission (kg.C/livestock animal/day)		
		Nakhon Ratchasima	**Chon Buri**	**Prachin Buri**
Farm	Electricity *	0.001±0.02	0.001±0.02	0.001±0.02
	Fuel for transpotation **	0.026±0.009	0.028±0.106	0.027±0.011
	Fuel for machine *** or LPG ****	N.D.	N.D.	N.D.
	Total C from energy/kg.livestock animal/day	0.027	0.029	0.028
	Total for energy/livestock animal/day	21.951×10^{-3}	25.439×10^{-3}	23.932×10^{-3}
Slaughterhouse	Electricity *	0.003±0.002	0.004±0.032	0.004±0.013
	Fuel for transpotation **	0.018±0.009	0.016±0.003	0.020±0.117
	Wood chaff LPG****	0.023±0.015	0.021±0.038	0.022±0.007
	Total C from energy/kg.livestock animal/day	0.044	0.041	0.46
	Total for energy/livestock anima/day	35.772×10^{-3}	35.965×10^{-3}	39.016×10^{-3}
Total $C_{emission}$ from energy of two source	**kg.C/kg.livestock animal/day**	**0.071**	**0.070**	**0.102**
	kg.C/livestock animal/day	**57.723×10^{-3}**	**61.404×10^{-3}**	**63.248×10^{-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_2/1 kg.LPG 0r 0.848 kg.C/1 kg.LPG. N.D. = not defection.

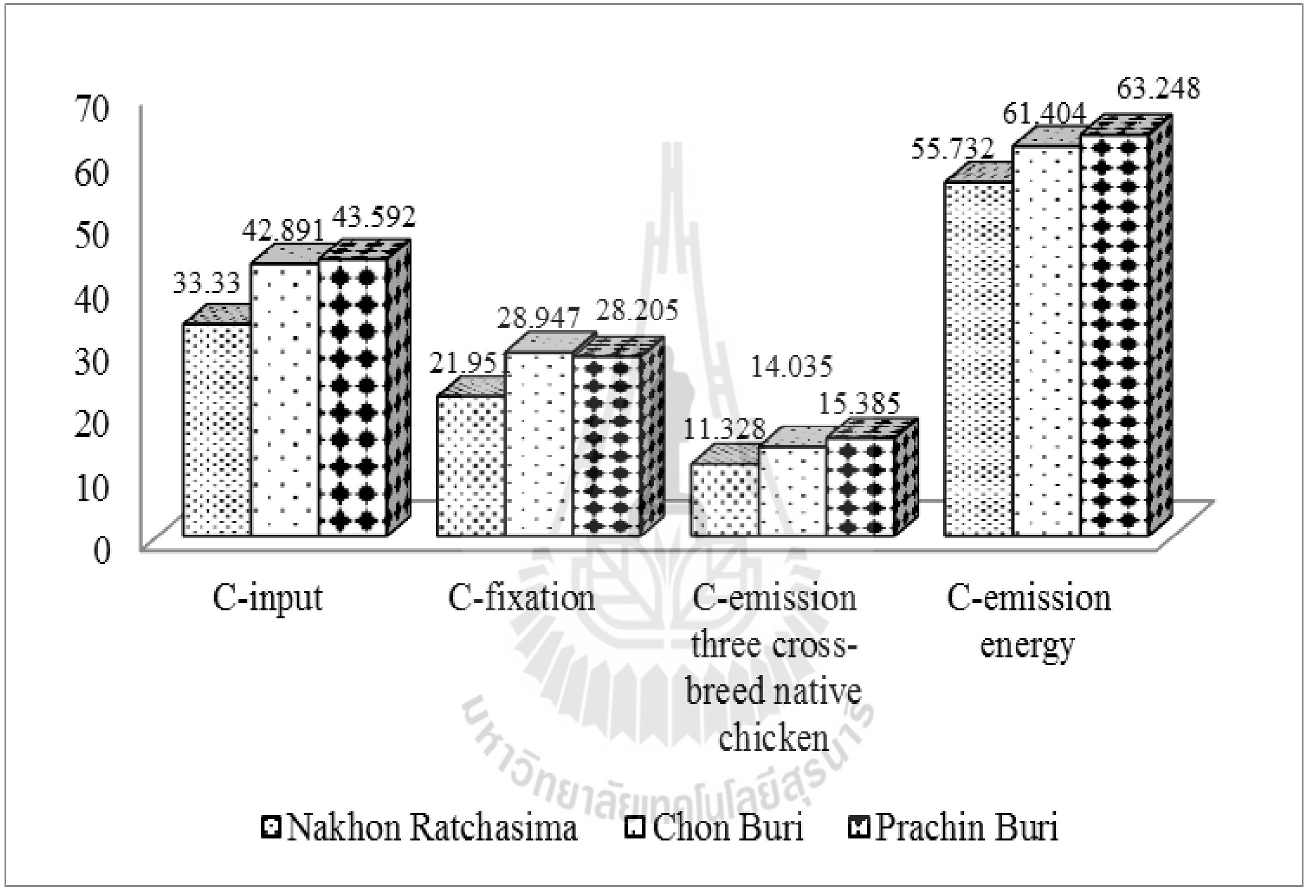


Figure 4.10 Carbon massflow of three breed-cross native chicken production in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces Thailand.

4.1.2.4 Carbon massflow of pekin ducks in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces

The carbon contents in the unit of kg carbon per kg livestock production per day (kg.C/kg.livestock animal/day) were used to study the comparison of carbon massflow from animal feed for feeding to biomass for different pekin duck (C-input), the carbon mass which was fixed in the livestock animal bodies (C-fixation) and the carbon emitted in the forms of CO_2 and CH_4 from faeces, digestion and respiration (C-emission) in Nakhon Ratchasima Chon Buri and Prachin Buri provinces Thailand.

The results found that carbon massflow from animal feed for feeding of pekin ducks (C_{input}) in Chon Buri province had the highest value at 36.364×10^{-3} kg.C/kg.pekin duck/day, whereas in Prachin Buri province had carbon input at 35.417×10^{-3} kg.C/kg.pekin duck/day and the lowest in Nakhon Ratchasima province at 33.438×10^{-3} kg.C/kg.pekin duck/day.

In addition, the rate of carbon input from animal feed by consumption including carbon fixation in livestock bodies ($C_{fixation}$) in Chon Buri province had the highest value at 25.078×10^{-3} followed by in Prachin Buri province at 24.405×10^{-3} and Nakhon Ratchasima province at 23.438×10^{-3} kg.C/kg.pekin duck/day, respectively.

However, the carbon emissions from enteric fermentation, faeces and respiration (C-emission) rankings of the highest to the lowest of C-emission were Chon Buri, Prachin Buri and Nakhon Ratchasima provinces at 11.285×10^{-3}, 11.012×10^{-3} and 10.000×10^{-3} kg.C/kg.pekin duck/day, respectively. This is probably because of the different farm management.

Furthermore, the carbon emission from the use of energy in farms and slaughterhouses were also important. The study found that in Nakhon Ratchasima province had the highest value at 64.375×10^{-3} kg.C/kg.pekin duck/day. In Prachin Buri province had carbon emission at 62.696×10^{-3} kg.C/kg.pekin duck/day and Chon Buri province had the lowest carbon emission value at 59.373×10^{-3} kg.C/kg.pekin duck/day. This due to the distance from animal feed factories to farms, hatcheries to farms, farms to slaughterhouses and slaughterhouses to markets as shown in Tables 4.13 to 4.14 and Figure 4.11.

According to the carbon emission from pekin duck meat production the results showed that the performance comparison of carbon fixation efficiency $[(C_{-input} - C_{-emission}) / C_{-input}]$ of pekin duck meat production in three provinces were Nakhon Ratchasima > Chon Buri > Prachin Buri provinces at 70.09%, 68.97% and 68.91%, respectively. This is another reason to support that pekin duck meat productions in Nakhon Ratchasima province create the lowest environmental impacts as shown in Table 4.13.

Table 4.13 Rates of carbon input, carbon fixation and carbon emission of pekin ducks compere the same weight in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (mean ± S.D.).

Animal	**Mean live animal weight in farm (kg./ind)**	**C-input (kg.C/livestock animal/day)**	**C-input/same livestock animal (kg. C-input/kg livestock animal /day)**	**C-fixation (kg.C/ livestock animal /day)**	**C-fixation/same livestock animal (kg. C-input/kg livestock animal /day)**	**C-emission (kg.C/livestock animal/day)**	**C-emitted/same livestock animal C-emission/kg livestock animal /day)**	**C- emission/ C- input (%)**	**C- emission/ C- fixation (%)**	**Fixation effiedcy C = (C-input – C-emission)/ C-input (%)**
Nakhon Ratchasima	3.2	0.107±0.57	33.438×10^{-3}	0.075±.077	23.438×10^{-3}	0.032±0.76	10.000×10^{-3}	29.91	42.67	70.09
Chon Buri	3.19	0.116±0.63	36.364×10^{-3}	0.080±0.89	25.078×10^{-3}	0.036±0.82	11.285×10^{-3}	31.03	45.00	68.97
Prachin Buri	3.36	0.119±0.51	35.417×10^{-3}	0.082±82	24.405×10^{-3}	0.037±0.92	11.012×10^{-3}	31.09	45.12	68.91

Table 4.14 Average of C-emission from energy in farm and slaughterhouse of pekin ducks cken in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (mean ± S.D.).

Average C from energy		C-emission (kg.C/livestock animal/day)		
		Nakhon Ratchasima	Chon Buri	Prachin Buri
Farm	Electricity *	0.003±0.006	0.004±0.024	0.005±0.06
	Fuel for transpotation **	0.049±0.001	0.046±0.017	0.045±0.081
	Fuel for machine*** or LPG****	N.D.	N.D.	N.D.
	Total C from energy/kg.livestock animal/day	0.052	0.050	0.050
	Total for energy/livestock animal/day	16.250×10^{-3}	15.674×10^{-3}	14.149×10^{-3}
Slaughterhouse	Electricity *	0.016±0.007	0.016±0.067	0.016±0.147
	Fuel for transpotation **	0.003±0.005	0.002±0.001	0.002±0.045
	Wood chaff LPG****	0.140±0.031	0.132±0.002	0.134±0.002
	Total C from energy/kg.livestock animal/day	0.154	0.150	0.152
	Total for energy/livestock anima/day	48.125×10^{-3}	47.022×10^{-3}	45.238×10^{-3}
Total $C_{emission}$ from energy of two source	**kg.C/kg.livestock animal/day**	**0.206**	**0.200**	**0.202**
	kg.C/livestock anima/day	**64.375×10^{-3}**	**62.696×10^{-3}**	**59.387×10^{-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_2/1 kg.LPG 0r 0.848 kg.C/1 kg.LPG. N.D. = not defection

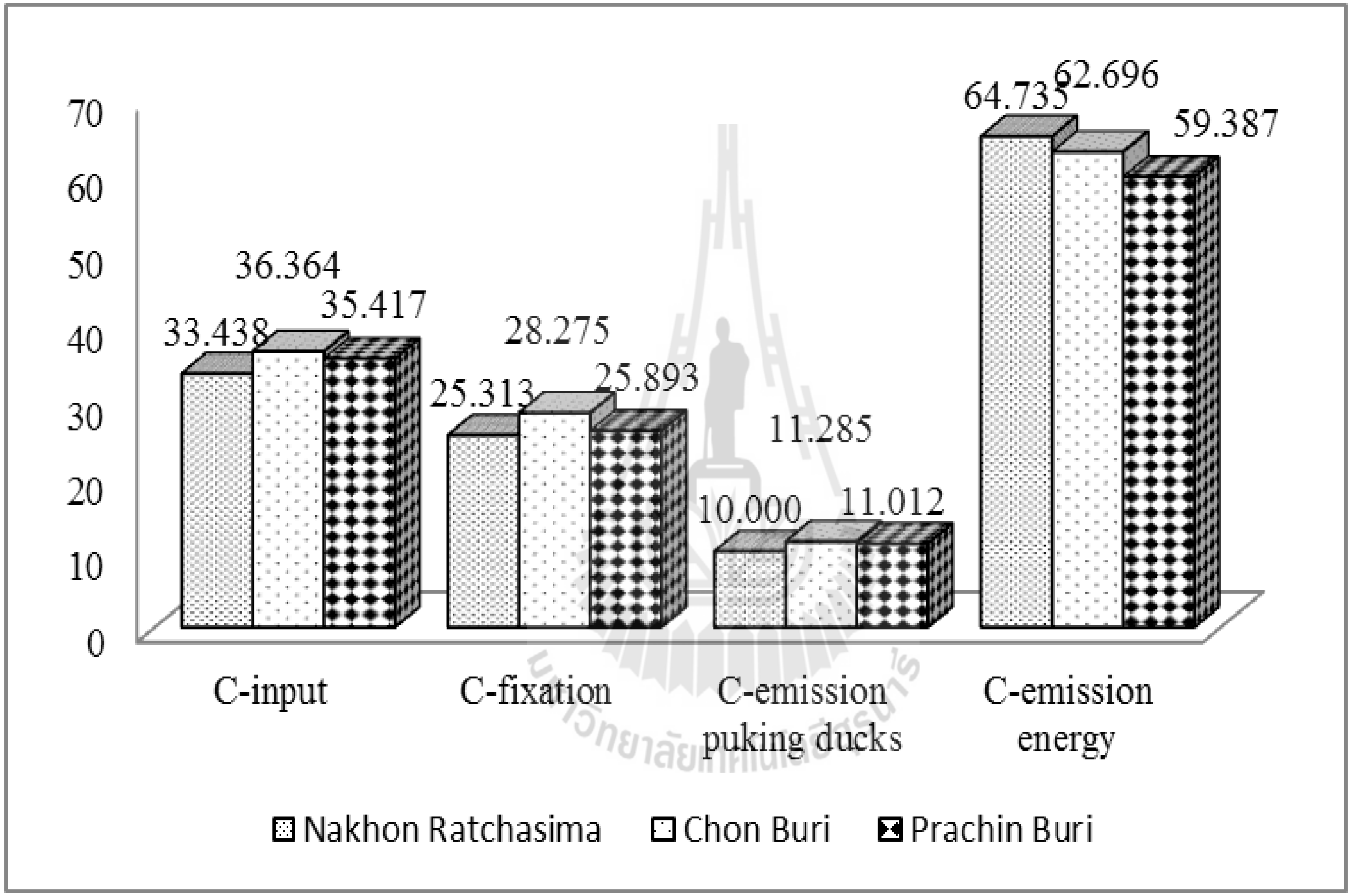


Figure 4.11 Carbon massflow of pekin ducks production in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces Thailand.

4.1.2.5 Carbon massflow of laying ducks in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces

The carbon contents in the unit of kg carbon per kg livestock production per day (kg.C/kg.livestock animal/day) were used to study the comparison of carbon massflow from animal feed for feeding to biomass for different laying duck (C-input), the carbon mass which was fixed in the livestock animal bodies (C-fixation) and the carbon emitted in the forms of CO_2 and CH_4 from faeces, digestion and respiration (C-emission) in Nakhon Ratchasima Chon Buri and Prachin Buri provinces Thailand.

The results found that carbon massflow from animal feed for feeding of laying ducks ($C\text{-}_{input}$) in Prachin Buri province had the highest value at 90.361×10^{-3} kg.C/kg.laying duck/day. While in Nakhon Ratchasima province had carbon input at 88.000×10^{-3} kg.C/kg.laying duck/day and the lowest in Chon Buri province at 78.125×10^{-3} kg.C/kg.laying duck/day. This may be because of the different farm management, kind of animal feed and body live weight of laying ducks.

Additionally, the rate of carbon input from animal feed by consumption including carbon fixation in laying duck bodies and eggs ($C\text{-}_{fixation}$) rankings of the highest to lowest were Prachin Buri, Nakhon Ratchasima and Chon Buri provinces at 62.651×10^{-3}, 61.143×10^{-3} and 50.625×10^{-3} kg.C/kg.laying duck/day, respectively.

Moreover, the carbon emission from enteric fermentation, faeces and respiration ($C\text{-}_{emission}$) in Prachin Buri province had the highest carbon emission at 27.711×10^{-3} kg.C/kg.laying duck/day. In Chon Buri province had the carbon emission at 27.049×10^{-3} kg.C/kg.laying duck/day and in Nakhon Ratchasima province has the lowest carbon emission at 26.875×10^{-3} kg.C/kg.laying duck/day.

Furthermore, the carbon emission from the use of energy in farms and slaughterhouses were also important. The study found that in Nakhon Ratchasima province had the highest value at 65.143×10^{-3} kg.C/kg.laying duck/day. In Chon Buri province had carbon emission at 35.625×10^{-3} kg.C/kg.laying duck/day and Prachin Buri province had the lowest carbon emission value at 34.940×10^{-3} kg.C/kg.laying duck/day. The distances from animal feed factories to farms, hatcheries to farms, farms to slaughterhouses, slaughterhouses to markets and distance from farms to the markets for transporting eggs were important factors in carbon emission which are shown in Tables 4.15 to 4.16 and Figure 4.12.

In agreement with the carbon emission from meat egg productions the result showed that the performance comparison of carbon fixation efficiency $[(C_{\text{-input}} - C_{\text{-emission}}) / C_{\text{-input}}]$ of meat egg productions in three provinces were Nakhon Ratchasima > Prachin Buri > Chon Buri provinces at 69.85%, 69.33% and 64.80%, respectively. This is another reason to support that laying duck meat and egg productions in Nakhon Ratchasima province create the lowest environmental impacts as shown in Table 4.15.

Table 4.15 Rates of carbon input, carbon fixation and carbon emission of laying ducks compere the same weight in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (mean ± S.D.).

Animal	**Mean live animal weight in farm (kg./ind)**	**C-input (kg.C /livestock animal /day)**	**C-input/same livestock animal (kg. C-input/kg livestock animal /day)**	**C-fixation (kg.C/ livestock animal /day)**	**C-fixation/same livestock animal (kg. C-input /kg livestock animal /day)**	**C-emission (kg.C/ livestock animal/day)**	**C-emitted/ same livestock animal C-emission/kg livestock animal /day)**	**C- emission/ C- input (%)**	**C- emission/ C- fixation (%)**	**Fixation effiedcy C = (C-input – C-emission)/ C-input (%)**
Nakhon Ratchasima	1.75	0.154±0.52	88.000×10^{-3}	0.107±1.23	61.143×10^{-3}	0.047±1.46	26.857×10^{-3}	30.52	43.93	69.85
Chon Buri	1.60	0.125±0.62	78.125×10^{-3}	0.081±1.09	50.625×10^{-3}	0.044±1.35	27.049×10^{-3}	34.62	54.32	64.80
Prachin Buri	1.66	0.150±0.63	90.361×10^{-3}	0.104±1.32	62.651×10^{-3}	0.046±1.28	27.711×10^{-3}	30.67	44.23	69.33

Table 4.16 Average of C-emission from energy in farm and slaughterhouse of laying ducks in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces (mean ± S.D.).

	Average C from energy	**C-emission (kg.C/livestock animal/day)**		
		Nakhon Ratchasima	**Chon Buri**	**Prachin Buri**
Farm	Electricity *	0.013±0.004	0.013±0.026	0.013±0.007
	Fuel for transpotation **	0.035±0.049	0.037±0.073	0.039±0.016
	Fuel for machine*** or LPG****	0.008±0.009	0.007±0.003	0.006±0.047
	Total C from energy/kg.livestock animal/day	0.056	0.057	0.058
	Total for energy/livestock animal/day	32.000×10^{-3}	35.625×10^{-3}	34.940×10^{-3}
Slaughterhouse	Electricity *	0.005±0.004	N.D.	N.D.
	Fuel for transpotation **	0.032±0.0147	N.D.	N.D.
	Wood chaff LPG****	0.021±0.009	N.D.	N.D.
	Total C from energy/kg.livestock animal/day	0.058	N.D.	N.D.
	Total for energy/livestock anima/day	33.143×10^{-3}	N.D.	N.D.
Total $C_{emission}$ from energy of two source	**kg.C/kg.livestock animal/day**	**0.076**	**0.57**	**0.58**
	kg.C/livestock animal t/day	**65.143×10^{-3}**	**35.625×10^{-3}**	**34.940×10^{-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_2/1 kg.LPG 0r 0.848 kg.C/1 kg.LPG. N.D. = not defection

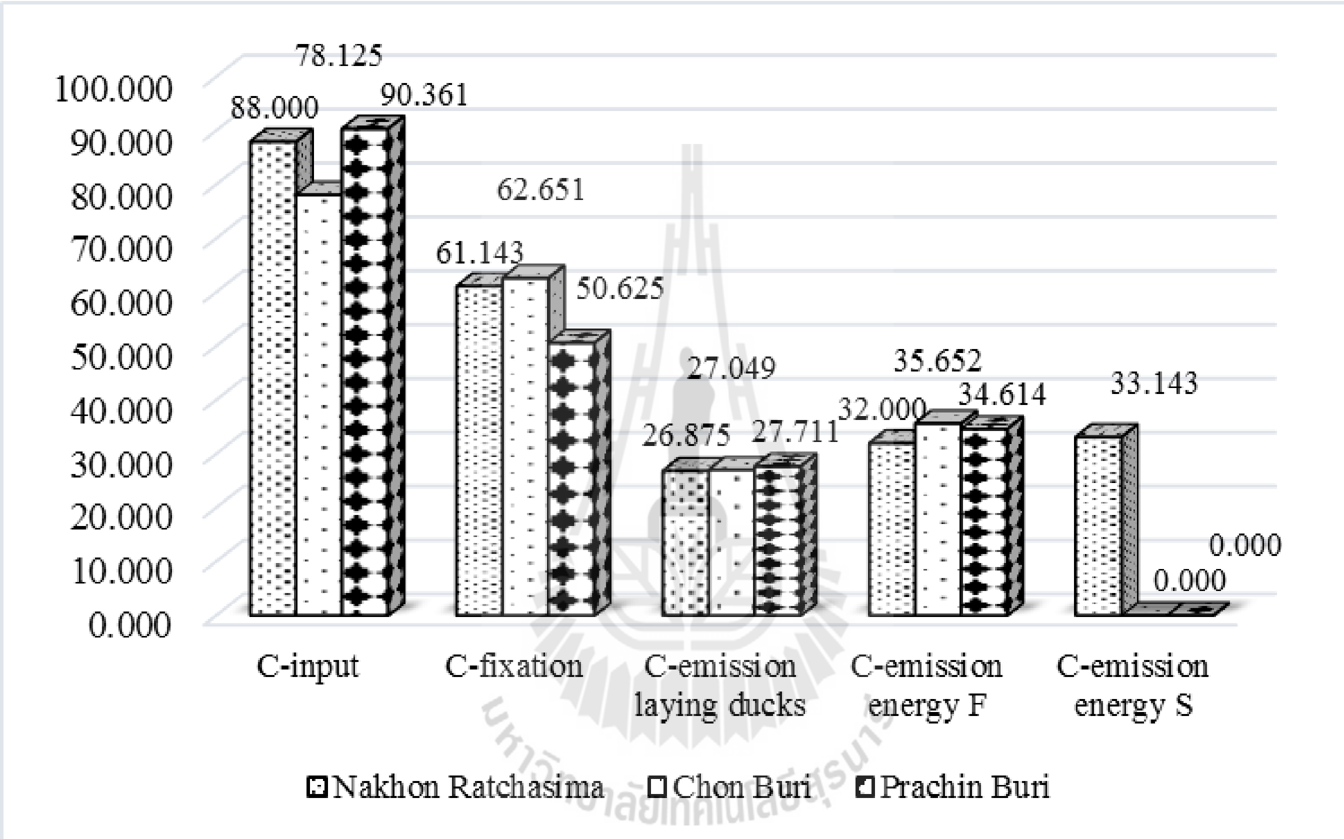


Figure 4.12 Carbon massflow of laying ducks production in Nakhon Ratchasima, Chon Buri and Prachin Buri.

4.2 Carbon emission from energy use in meat and egg production

The survey of farms and slaughterhouses in studied provinces found that swine farms, goat farms, three breed-cross native chicken farms, pekin duck farms and laying duck farms had used much energy for raising livestock per kilogramme livestock animal per day (kg.C/kg.livestock animal). Most of energy used such as energy for water pumps, transportation of animals, eggs, feed and animals to slaughterhouses, and LPG or electricity for incubation of small swine and birds. Carbon emission from these parts of farm, the livestock animal farms were used for feed transportation and chicks, ducking and mature laying ducks to farms and slaughterhouses besides egg transportation to markets. The result shown that the total carbon emissions from energy at the same weight of animal productions, goats > three breed-cross native chicken > laying ducks > pekin ducks > swine were 62.969x10^{-3} kg.C/goat/day, 59.332 x10^{-3} kg.C/three breed-cross native chicken /day, 50.899x10^{-3} kg. C/ laying duck/day, 41.231x10^{-3} kg. C/ pekin duck/day and 32.040x10^{-3} kg.C/swine/day which are shown in Table 4.17.

Additionally, slaughterhouses used most of energy for water pumps, light and transportation of meat livestock production. Besides these, slaughterhouses used wood, chaff or LPG for boiling water in cleaning process, taking of hair and leather of livestock animals. The result found that the total carbon emission from these study were three breed-cross native chicken > laying ducks > pekin ducks > swine > goats which were 35.593x10^{-3} kg. C/ three breed-cross native chicken/day, 34.132x10^{-3} kg.C/laying duck/day, 25.864x10^{-3} kg.C/pekin duck/day, 23.651x10^{-3} kg.C/swine/day and 10.286x10^{-3} kg.C/goat/day as shown in Table 4.7. Considering the same weight of animal, carbon emission from goat production was the highest at 62.696×10^{-3} kg.C/goat/day as shown in Table 4.7

Consequently, the comparison of farms and slaughterhouses found that most of carbon emissions from egg productions were used for transportation, while swine, goats, three breed-cross native chicken, pekin ducks and decommissioned laying duck were used in slaughterhouses. The total carbon emission from the use of energy from farms and slaughterhouses found that swine production from energy used at 3.17 kg.C/livestock animal/day. According to the same weight found that swine production from the use of energy the lowest value of the total carbon emission from farms and slaughterhouses at 32.040×10^{-3} kg. C/ swine/day. In the other hand, the meat goat production from the use of energy was the highest value at 62.969×10^{-3} kg. C/ goat/day. This studied the use of energy from fuel, LPG, chaff and wood in livestock meat productions which are shown in Figure 4.13.

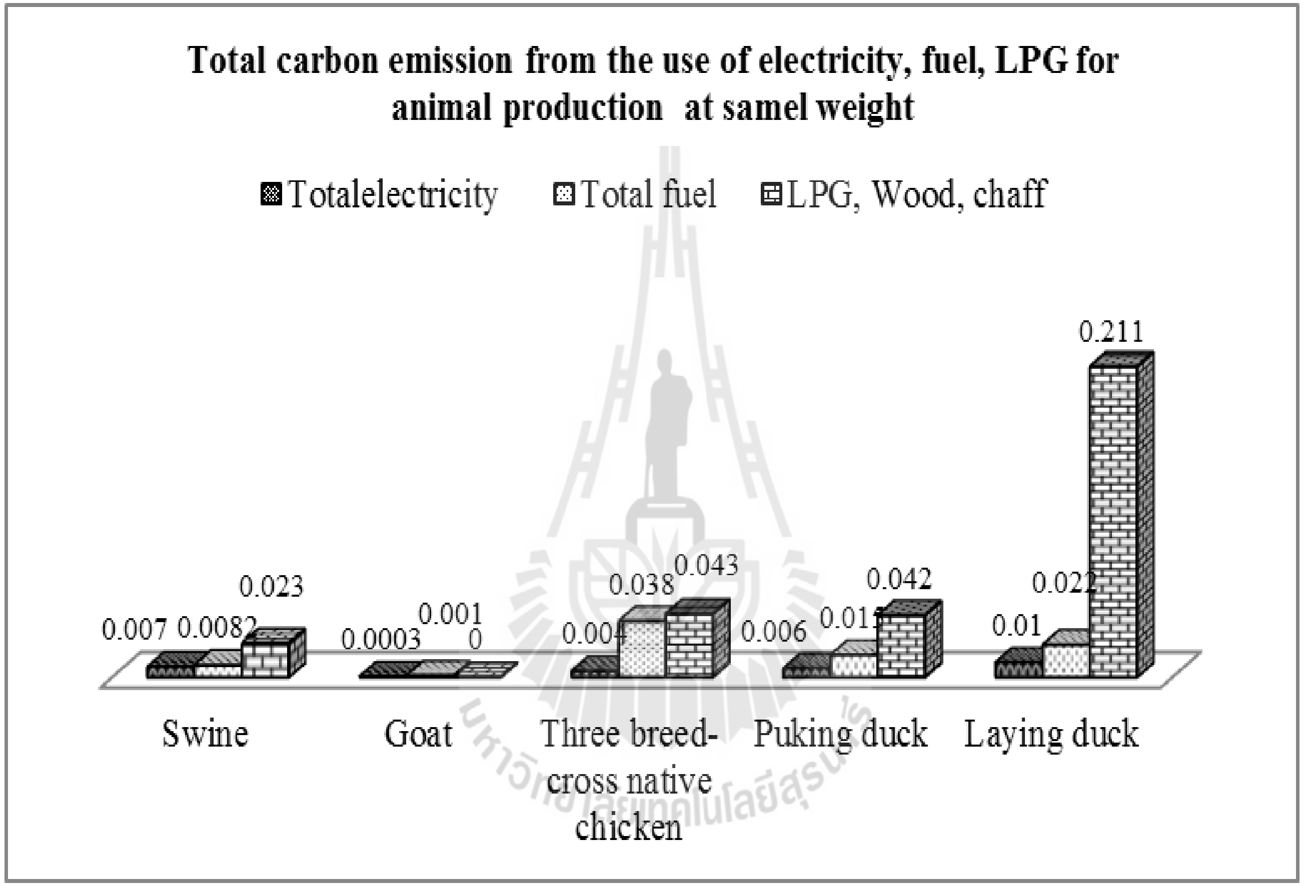


Figure 4.13 Total carbon emission from the use of electricity, fuel, LPG for production of swine, goats, three breed-cross native chicken, pekin ducks and laying ducks meat at same weight.

Table 4.17 Average of C-emission from energy in farm and slaughterhouse (mean ± S.D.).

Average C from energy		C-emission (kg.C/kg.livestock animal/day)				
		Swine	**Goat**	**Three breed-cross native chicken**	**Pekin duck**	**Laying duck**
Farm	Electricity *	0.02±0.02	0.002±0.00	0.001±0.02	0.003±0.06	0.013±0.04
	Fuel for transpotation **	0.81±0.85	1.93±0.03	0.027±0.149	0.047±0.081	0.037±0.073
	Fuel for machine*** or LPG****	N.D.	N.D.	N.D.	N.D.	N.D.
	Total C from energy/kg.livestock animal/day	0.83	1.932	0.028	0.05	0.05
	Total for energy/livestock animal/day	8.389x10^{-3}	52.414x10^{-3}	23.729x10^{-3}	15.385x10^{-3}	29.940x10^{-3}
Slaughterhouse	Electricity *	0.05±0.04	0.009±0.004	0.004±0.032	0.016±0.007	0.017±0.016
	Fuel for transpotation **	0.01±0.00	0.37±0.0016	0.002±0.009	0.002±0.005	0.011±0.002
	Wood chaff LPG****	2.28±1.02	N.D.	0.036±0.038	0.066±0.002	0.007±0.001
	Total C from energy/kg.livestock animal/day	2.34	0.379	0.042	0.084	0.035
	Total for energy/livestock anima/day	23.651x10^{-3}	10.282x10^{-3}	35.593x10^{-3}	25.846x10^{-3}	20.958x10^{-3}
Total $C_{emission}$ from energy of two source	**kg.C/kg.livestock animal /day**	**3.170**	**2.311**	**0.070**	**0.134**	**0.085**
	kg.C/livestock animal/day	**32.040x10^{-3}**	**62.696x10^{-3}**	**59.322x10^{-3}**	**41.231x10^{-3}**	**50.898x10^{-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 0r 0.848 kg.C/1 kg.LPG. N.D. = not defection.

Nonetheless, at the same weight for each livestock animal (1 kg of live-weight) it was found that the goat emitted carbon from the use of energy for meat productions at 25.47% of all carbon emission, followed by three breed-cross native chicken meat productions at 24.10%, laying duck productions at 20.67%, pekin duck meat production at 16.75% and pork production at 13.01% as illustrated in Figure 4.14.

However, the total carbon emission from goat productions were the highest at 73.369×10^{-3} kg. C/ kg.goat duck/day as shown in Table 4.20. Therefore, it can be concluded that goat productions from livestock farms create higher environmental impact than three breed-cross native chicken production, pekin duck production, laying duck production and pork productions when compered at the 1 kg live-weight of livestock animals (Formula 4.10).

$$C\text{-emission}_{energy} = (1.157)\ \text{Swine} + (0.844)\ \text{Goat} + (0.026)\ \text{Three breed-cross native chicken} + (0.049)\ \text{Pekin duck} + (0.031)\ \text{Laying duck} \qquad (4.10)$$

Where:

$C\text{-emission}_{energy}$ = total carbon emission from body of swine, goats, three breed-cross native chickens, pekin ducks and laying ducks (ton carbon per year).

Swine = number of swine (kg).

Goats = number of goats (kg).

Three breed-cross native chicken = number of three breed-cross native chicken (kg).

Pekin ducks = number of pekin ducks (kg).

Laying ducks = number of laying ducks (kg).

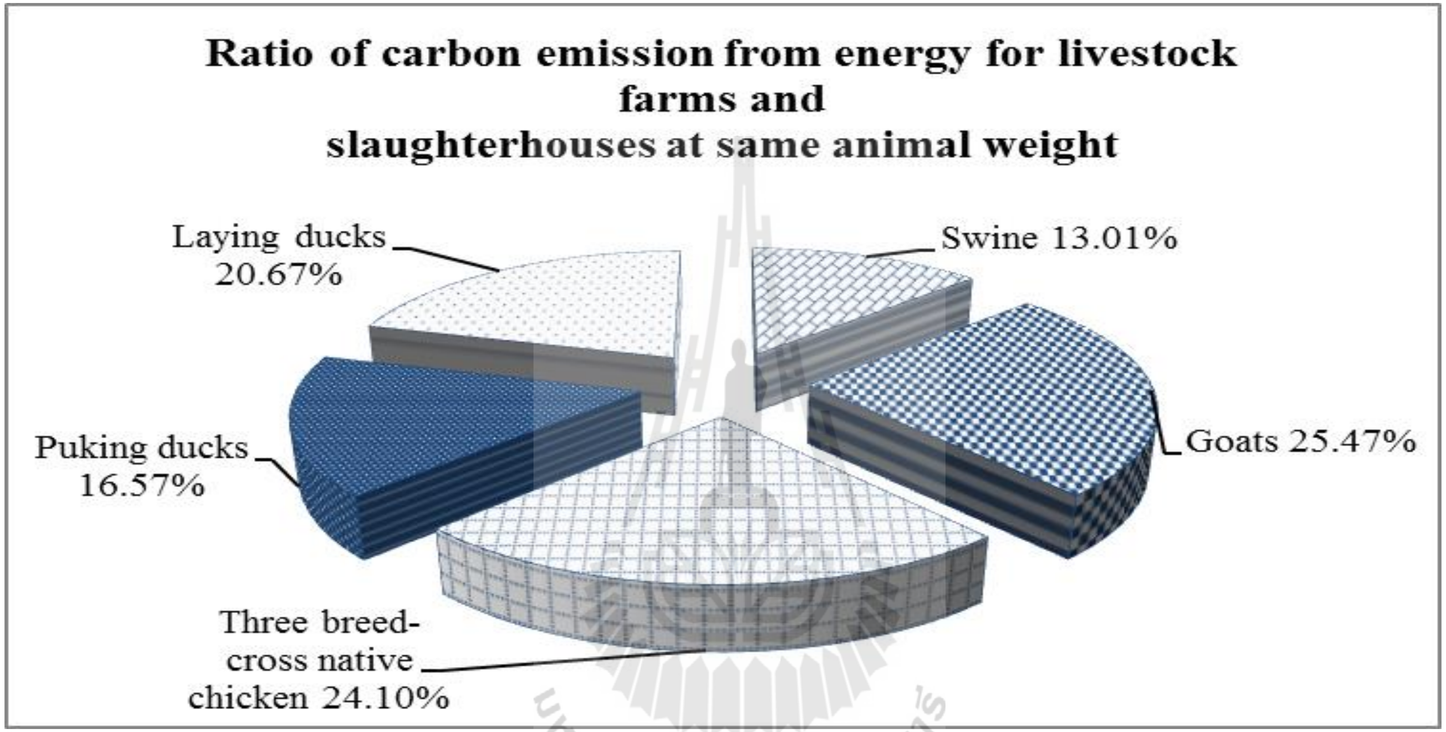


Figure 4.14 Ratio of carbon emission from energy for pork, goat meat, chicken meat, duck meat and egg of farms and slaughterhouses at same animal weight.

4.3 Relationship between percentage of carbon content in animal feed, meat, egg and faeces and livestock animal productions

The results of 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 day per individual 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.

The laying ducks released the highest faeces at 33.91% of animal feed followed by three breed-cross native chicken at 22.45%, goats at 22.19%, pekin ducks at 19.31% and swine at 2.14%, respectively as shown in Table 4.18. The swine consumed only 1.94% of feed and released only 0.51% of swine faeces which was positively correlated with relationship between C-input and C-emission$_{\text{livestock animal}}$.

Table 4.18 Average and relationship between carbon, dry weight of animal feed and faeces from each animal per day and average rearing duration of each animal (mean ± S.D.).

Animal	Average rearing duration (day)	Dry faeces (kg/kg. livestock animal/day)	Dry food plant for animal consumption (kg/kg. livestock animal/day)	Dry wt CH_4 form animal per kg. dry food plant	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 food plant	C in form of CO_2 + $CH_{4\ \mathrm{Per\ food\ plant}}$	C faeces per C food plant
Swine	147.24±2.64	0.784	2.24±0.04	0.38%	2.26%	0.79%	3.50%	8.58%	21.34%
Goat	122.61±3.92	0.425	1.13±1.68	0.42%	3.07%	1.16%	37.79%	9.82%	23.48%
Three breed-cross native chicken	56.76±4.17	0.024	0.047±0.48	0.00%	3.98%	2.03%	51.01%	4.35%	35.66%
Pekin duck	45.86±2.77	0.062	0.114±0.57	0.00%	3.51%	1.91%	33.90%	4.98%	36.79%
Laying duck	492.58±8.49	0.074	0.143±0.57	0.00%	8.56%	4.43%	51.57%	5.16%	37.83%

Table 4.19 Relationship between moisture, volatile solid and carbon content of food, faeces, meat, entrail and egg.

Animal	Moisture (%)	Total volatile solid (%TVS)	Ash (%)	Carbon content (%C)	Relationship between %TVS and %C	R^2
Pig food	6.48±1.26	72.28±2.42	27.72±2.42	44.02±2.05	%TVS = 0.93(%C) + 28.43	0.82
Pork	67.94±2.63	84.02±2.17	15.98±2.17	44.80±3.09	%TVS = 0.86(%C) + 47.26	0.74
Pig heart	69.05±2.40	81.15±0.82	18.85±0.82	48.94±0.71	%TVS = 0.26(%C) + 53.00	0.87
Pig liver	75.08±1.72	80.40±1.35	18.60±1.35	51.37±7.21	%TVS = 0.21(%C) + 86.48	0.64
Pig pancrease	76.89±1.60	80.11±0.90	19.89±0.90	39.63±3.84	%TVS = 0.16(%C) + 77.80	0.78
Pig speen	73.66±3.36	76.98±0.07	23.03±0.07	44.16±4.25	%TVS = 0.19(%C) + 63.21	0.81
Pig stomache	68.09±3.70	82.18±0.25	17.82±0.25	43.31±4.73	%TVS = 0.07 (%C) + 78.72	0.87
Pig intestine	76.46±4.72	82.33±0.29	17.67±0.29	43.86±4.09	%TVS = 0.05(%C) + 81.32	0.79
Pig rectum	80.74±1.70	76.86±1.20	23.14±1.20	45.28±1.85	%TVS = 0.19(%C) + 84.33	0.84
Pig faeces	65.57±6.54	60.30±3.40	39.7±3.40	34.98±1.83	%TVS = 1.86(%C) - 2.59	0.97
Pig entrail	73.51±3.49	80.86±1.83	19.14±1.83	47.67±4.95	%TVS = 0.25(%C) + 69.00	0.65
TNC food	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 = 0.59x + 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

Table 4.19 Relationship between moisture, volatile solid and carbon content of food, faeces, meat, entrail and egg (Continued).

Animal	Moisture (%)	Total volatile solid (%TVS)	Ash (%)	Carbon content (%C)	Relationship between %TVS and %C	R^2
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
Pekin duck food	8.45±1.25	72.82±2.07	27.18±2.07	44.06±4.52	%TVS = 0.50(%C) + 45.01	0.78
Pekin duck meat	67.71±6.57	81.37±4.01	18.63±4.01	48.40±6.21	%TVS = 0.89x + 49.97	0.83
Pekin duck tendon	61.08±8.22	90.97±1.26	9.03±1.26	44.88±0.79	%TVS = 1.56(%C) + 20.87	0.97
Pekin duck liver	66.92±0.86	85.63±1.31	14.37±1.31	46.71±1.18	%TVS = 1.05(%C) + 36.61	0.86
Pekin duck heat	62.66±0.36	82.73±0.96	17.27±0.96	49.78±0.28	%TVS = 4.38(%C) - 82.67	0.90

Table 4.19 Relationship between moisture, volatile solid and carbon content of food, faeces, meat, entrail and egg (Continued).

Animal	Moisture (%)	Total volatile solid (%TVS)	Ash (%)	Carbon content (%C)	Relationship between %TVS and %C	R^2
Pekin duck gizzard	70.94±0.28	76.04±1.09	23.96±1.09	45.14±0.79	%TVS = 0.76(%C) + 27.72	0.70
Pekin duck skin	68.49±2.12	87.50±0.88	12.50±0.88	36.30±1.94	%TVS = 0.45(%C) + 70.96	0.58
Pekin duck wing	50.45±0.99	77.11±0.81	22.89±0.81	38.18±1.26	%TVS = 0.61(%C) + 48.94	0.89
Pekin duck feet	64.79±1.63	73.45±0.61	26.55±0.61	33.92±2.24	%TVS = 0.46(%C) + 62.48	0.92
Pekin duck leg	65.07±0.82	79.97±1.76	20.03±1.76	35.19±1.01	%TVS = 0.66(%C) + 26.43	0.74
Pekin duck faeces	71.51±22.31	66.39±9.16	33.61±9.16	34.07±6.13	%TVS = 0.77(%C) + 33.23	0.72
Laying duck food	7.45±1.25	71.82±2.07	28.18±2.07	44.06±4.52	%TVS = 0.40(%C) +455.01	0.78
Laying duck meat	65.71±6.57	74.37±4.01	25.63±4.01	46.40±6.21	%TVS = 0.59x + 35.97	0.83
Laying duck tendon	61.08±8.22	69.97±1.26	30.03±1.26	34.88±0.79	%TVS = 0.96(%C) + 20.87	0.97
Laying duck liver	71.92±0.86	85.63±1.31	14.37±1.31	44.71±1.18	%TVS = 1.05(%C) + 46.61	0.90
Laying duck n heat	67.66±0.36	83.73±0.96	16.27±0.96	46.78±0.28	%TVS = 3.38(%C) - 82.67	0.89
Laying duck gizzard	69.94±0.28	80.04±1.09	19.96±1.09	45.14±0.79	%TVS = 0.86(%C) + 27.72	0.70
Laying duck skin	78.49±2.12	92.50±0.88	7.50±0.88	38.30±1.94	%TVS = 0.45(%C) + 70.96	0.78
Laying duck wing	68.45±0.99	77.11±0.81	22.89±0.81	36.18±1.26	%TVS = 0.61(%C) + 48.94	0.89

Table 4.19 Relationship between moisture, volatile solid and carbon content of food, faeces, meat, entrail and egg (Continued).

Animal	**Moisture (%)**	**Total volatile solid (% TVS)**	**Ash (%)**	**Carbon content (%C)**	**Relationship between %TVS and %C**	**R^2**
Laying duck skin	78.49±2.12	92.50±0.88	7.50±0.88	38.30±1.94	%TVS = 0.45(%C) + 40.96	0.78
Laying duck wing	68.45±0.99	77.11±0.81	22.89±0.81	36.18±1.26	%TVS = 0.61(%C) + 48.94	0.89
Laying duck feet	65.79±1.63	73.45±0.61	26.55±0.61	41.92±2.24	%TVS = 0.76(%C) + 62.48	0.92
Laying duck leg	66.07±0.82	76.97±1.76	24.03±1.76	43.19±1.01	%TVS = 1.16(%C) + 26.43	0.64
Laying duck faeces	65.51±22.31	66.39±9.16	33.61±9.16	34.07±6.13	%TVS = 0.87(%C) + 33.23	0.82
Duckweed	81.57±0.62	78.31±3.15	21.69±3.15	33.58±4.05	%TVS = 0.73(%C) + 34.92	0.89
Egg	73.55±10.62	90.89±2.51	9.11±2.51	50.99±1.17	%TVS = 1.01(%C) - 9.43	0.88
Layer faeces	70.38±12.21	67.85±7.41	32.15±7.41	34.09±2.56	%TVS = 1.37(%C) - 22.80	0.87
Golden applesnail	76.45±1.25	72.82±2.07	27.18±2.07	47.06±4.52	%TVS = 0.80(%C) + 35.01	0.78
Rice	13.08±8.22	80.97±1.26	19.03±1.26	44.88±0.79	%TVS = 1.56(%C) + 20.87	0.97
Rice bran	11.92±0.86	75.63±1.31	24.37±1.31	40.71±1.18	%TVS = 0.95(%C) + 36.61	0.93
Rice broken	9.66±0.36	77.73±0.96	22.27±0.96	39.78±0.28	%TVS = 1.38(%C) - 42.67	0.79
Laying duck food 2	73.66±0.36	85.73±0.96	14.27±0.96	43.78±0.28	%TVS = 2.38(%C) - 62.67	0.89
Laying duck food (*Azolla pinnata*)	80.94±0.28	80.04±1.09	19.96±1.09	35.14±0.79	%TVS = 0.46(%C) + 27.72	0.70

The percentage of moisture, volatile solids (TVS), ash and carbon content in feed, egg, meat, entrails and faeces of livestock animals are illustrated in Table 4.19. Moreover, it also shows relationship between percentage of total volatile solids (%TVS) and percentage of carbon (%C) which help in analysis of percentage of carbon in laboratory. Simultaneously, the results of this study can be analyzed environmental impacts from each livestock production. The analysis is based on the Payoff Matrix Principle by using all alternatives such as livestock production and carbon emission scenarios (Table 4.20) then make the decision follow (Sullivan, Wicks and Jame, 2003).

Table 4.20 Carbon emission scenarios from livestock production follow the Payoff Matrix Principle.

Alternative of livestock	**Scenarios of carbon emission (kg.C/livestock animal/day)**	
	C-emission from animal	**C-emission from energy use**
Swine	2.78×10^{-3}	32.040×10^{-3}
Goats	10.40×10^{-3}	62.696×10^{-3}
Three breed-cross native chicken	13.33×10^{-3}	59.322×10^{-3}
Pekin ducks	10.77×10^{-3}	41.231×10^{-3}
Laying ducks	27.54×10^{-3}	29.940×10^{-3}

Analysis of the scenarios were applied the Laplace's Rule to choose the kind of livestock which caused the highest environmental impacts by setting the probability of the equal scenarios (n=2) as shown in Table 4.21. According to the Laplace's Rule, results of this analysis could be concluded that swine was the best alternative in livestock productions while goats created the highest environmental impacts. When considering special livestock meat productions the result found that the goat meat productions created the highest environmental impacts.

Table 4.21 Carbon emission scenarios for livestock production from the application of the Laplace's Rule.

Alternative of live stock	(C-emission from animal + C-emission from energy used) ÷ 2
Swine	(2.78 + 32.040) ÷ 2 = 17.14
Goats*	(10.40 + 62.969) ÷ 2 = 36.86
Three breed-cross native chicken	(13.33 + 59.322) ÷ 2 = 36.326
Pekin ducks	(10.77 + 41.231) ÷ 2 = 26.001
Laying ducks	(27.54 + 29.940) ÷ 2 = 28.74

Remark: *Selected livestock which created the maximum environmental impact.

Furthermore, the Maximum Rules was applied to indicate the environmental impacts of livestock production by selection of scenarios in Table 4.20 which get the maximum result and then select the maximum result was selected from every alternative again. It can be stated by this following mathematical model (Sullivan, Wicks and Jame, 2003):

$$\frac{\max}{i}\left[\frac{\max P_{ij}}{j}\right] \tag{4.11}$$

Where:

P_{ij} is the result of i from scenarios j in Table 4.20

The results were shown in Table 4.22 which found that swine production was the best alternative among the studied livestock farm. Because of swine farm caused the lowest environmental impacts among the studied livestock farms.

Table 4.22 Carbon emission scenarios for livestock production from the application of the Laplace's Rule.

Alternative of livestock	$\frac{\max P_{ij}}{i(x)}$
Swine	32.040x10^{-3}
Goats*	62.696x10^{-3}
Three breed-cross native chicken	59.322x10^{-3}
Pekin ducks	41.231x10^{-3}

Remark: *Selected livestock which created maximum environmental impact.

When the Minimax Regret Rule was applied to avoid the regret that the decision was already made in taking the poor alternative of livestock production. This could be done by selecting the maximum result in each carbon emission scenario from Table 4.20 and then this result was minus with all result of each carbon emission scenario. Consideration of the maximum result in each carbon emission scenarios then set the matrix (Table 4.23) and selected the maximum regret in each alternative of livestock production. Each alternative was selected to find minimum value again and can be shown as:

$$\frac{\min}{i}\left[\frac{\max R_{ij}}{j}\right] \quad (4.12)$$

Where:

R_{ij} is the sorrow value for alternative *i* and *j* of the various scenarios

Table 4.23 The sorrow value in each alternative of livestock production.

Alternative of livestock	Scenario of carbon emission (kg.C/livestovk animal/day)	
	C-emission from animal	**C-emission from energy use**
Swine	24.76	30.656
Goat	17.14	0
Three breed-cross native chicken	14.21	3.374
Pekin duck	16.77	21.465
Laying duck	0	32.756

Meanwhile, Table 4.24 showed the that result of swine farming and swine that pork productions were the best alternative and pekin duck meat productions followed by three breed-cross native chicken meat productions, goat meat productions and egg productions, respectively. When considering the meat productions of each livestock animal, the result found that goat meat production was the worst alternative among studied livestock animals.

Table 4.24 The maximum sorrow value of each alternative of livestock.

Alternative of livestock	$\max_{j} R_{ij}$
Swine	30.655
Goats	17.140
Three breed-cross native chicken*	14.21
Pekin ducks	21.465
Laying ducks	32.756

Remark: *Selected livestock which created maximum environmental impact.

According to theories and rules applied which mentioned above in making the decision on environmental impacts, it can be concluded that pork productions are the best alternative of livestock. In the other hand, the laying duck productions cause the highest environmental impacts followed by goat meat productions, three breed-cross native chicken meat productions, pekin duck productions and pork productions.

4.4 Guideline for the decrease of carbon emission from livestock meat and egg productions

4.4.1 Carbon emission from livestock productions

Total carbon emission from livestock animal bodies in forms of CO_2 and CH_4 from the respiration and digestion in each livestock animal and carbon emission from energy used of livestock farms, slaughterhouses and the markets in Nakhon Rstchasima, Chon Buri and Prachin Buri provinces. This studies found that the total carbon emission per kg per year for the production of swine, goats, three breed-cross native chicken, pekin ducks and laying ducks were 1.167, 0.984, 0.032, 0.062 and 0.048 ton.C per livestock animal per year, respectively. Base on the Principle of the Conservation of Mass (UNECE, 2004) and the result of this study can be used to indicate the total carbon emission for livestock production as shown in Formula 4.13 as follow:

$$\text{C-emission}_{\text{livestock animal + energy use}} = (1.167)\ \text{Swine} + (0.984)\ \text{Goat} + (0.032)\ \text{Three breed-cross native chicken} + (0.062)\ \text{Pekin duck} + (0.048)\ \text{Laying duck} \qquad (4.13)$$

Where:

$\text{C-emission}_{\text{livestock animal energy use}}$

= total carbon emission from body of swine, goats, three breed-cross native chickens, pekin ducks and laying ducks (ton carbon per year).

Swine = number of swine (kg).

Goats = number of goats (kg).

Three breed-cross native chickens = number of three breed-cross native chicken (kg).

Pekin ducks = number of pekin ducks (kg).

Laying ducks = number of laying ducks (kg).

4.4.2 Environmental impacts, perception and adoption of alternative systems

The results of carbon emission into the atmosphere from livestock productions from throughout the process of producing livestock animal to consumers can be discussed. Carbon emitted into the atmosphere due to the use of energy such as electricity, fuel and LPG particularly the energy fuel used for transportation. Consequently, the consideration to reduce carbon emission should focus on the issue of reducing energy consumption or modification guidelines for energy efficiency, which can reduce the amount of carbon emission from the production of swine, goats, three breed-cross native chicken, pekin ducks and laying ducks. Such as, the range of livestock farming, the farmers should use LPG as the energy source to aeration instead of the use of diesel oil. LPG has a higher efficiency in the combustion process including create less ash and environmental impacts than diesel oil. In addition, LPG releases heat energy about 11,832-12034 Kcal/kg equivalent to electricity at 13.70 kWh/kg (Vichit-Vadakan et al., 200).

Simultaneously, the guidelines to reduce carbon emission from energy used for transporting animal feed, transport small swine and birds and LPG including transport of livestock production to markets should be considered. The result showed that this sector had the most energy consumption and carbon emission. Likewise, it can be recommended that the farmers should reduce distance and reduce the numbers of trips for transportation for instance the farmers should by animal feed and LPG within the province or neighborhood with livestock farms. Moreover, the small slaughterhouses should be used LPG for boiling the water for water in cleaning processes, taking of hair and leather of livestock animals replace wood and chaff.

Furthermore, the alternative ways for the reducing of carbon emission from the production of swine, goats, three breed-cross native chicken, pekin ducks and laying ducks by ranking and selection of animal feed kind that should guide and encourage the farmers for livestock meat and egg productions. The results of this study recommend that pork production create the lowest carbon emission among these livestock animals.

In addition, the Farmers should take place within the wastewaters and slurry farm to produce bio-gas. To reduce methane emissions and renewable energy to farm another.

CHAPTER V

CONCLUSION

5.1 Conclusion of the study

The comparative studies of the carbon massflow, carbon fixation, carbon emission from swine, goat, three breed-cross native chicken, pekin duck and laying duck production in the Nakhon Ratchasima Chon Buri, and Prachin Buri provinces were conducted during October, 2011 to September, 2012.

The results found that the carbon massflow from food plants to animals ranking from the highest to the lowest of carbon input were goat, swine, laying duck, pekin duck and three breed-cross native chicken productions at 1.130±1.68 kg.C/goat/day, 0.942±0.04 kg.C/swine/day, 0.143±0.57 kg.C/laying duck/day, 0.114±0.58 kg.C/pekin duck/day and 0.047±0.48 kg.C/three breed-cross native chicken/day, respectively. In addition, the ranking of carbon fixation in animal bodies from the highest to the lowest were goats, swine, laying ducks, pekin ducks and three breed-cross native chicken at 0.713±1.14 kg.C/goat/day, 0.641±0.63 kg.C/swine/day, 0.094±1.18 kg.C/laying duck/day, 0.086±0.81 kg.C/pekin duck/day and 0.031±0.49 kg.C/three breed-cross native chicken/day, respectively. Moreover, the ranking of carbon emission from studied livestock from the highest to the lowest were goats, swine, laying ducks, pekin ducks and three breed-cross native chicken at 0.383±1.46 kg.C/goat/day, 0.275±0.58 kg.C/swine/day, 0.046±1.37 kg.C/laying duck/day, 0.035±0.79 kg.C/pekin duck/day and 0.016±0.63 kg.C/three breed-cross native chicken/day, respectively. Furthermore, the orders of carbon emission form energy use in farms and slaughterhouses from the highest to the lowest were from swine, goats, pekin ducks, laying ducks and three breed-cross native chicken, at 3.170±0.85 kg.C/swine/day, 2.311±0.04 kg.C/goat/day, 0.134±0.15 kg.C/pekin duck/day, 0.085±0.07 kg.C/laying duck/day and 0.070±0.06 kg.C/three breed-cross native chicken/day, respectively. The results also showed that the ranking of carbon fixation efficiency from the highest to the lowest of livestock were in swine (68.79%), pekin ducks (67.11%), laying ducks (65.74%), three breed-cross native chicken (64.85%) and goats (63.09%), respectively. It can be concluded that the swine emitted the least carbon in each day compared with these studied livestock that consumed the same amount of carbon. Consequently, the carbon emission from pork productions created the lowest the environmental problems compared to the other studied livestock.

The results of C-input, C-fixation C-emission of animals and C-emission from the use of energy from swine, goat, three breed-cross native chicken, pekin duck and laying duck productions can be shown in the formulas 5.1 to 5.4

$$\text{C-input}_{\text{livestock animal}} = (0.344)\ \text{Swine} + (0.412)\ \text{Goat} + (0.017)\ \text{Three breed-cross native chicken} + (0.042)\ \text{Pekin duck} + (0.052)\ \text{Laying duck} \tag{5.1}$$

$$\text{C-fixation}_{\text{livestock animal}} = (0.234)\ \text{Swine} + (0.260)\ \text{Goat} + (0.011)\ \text{Three breed cross native chicken} + (0.031)\ \text{Pekin duck} + (0.034)\ \text{Laying duck} \tag{5.2}$$

$$C\text{-emission}_{livestock\ animal} = (0.100)\ \text{Swine} + (0.140)\ \text{Goat} + (0.006)\ \text{Three breed-cross native chicken} + (0.028)\ \text{Pekin duck} + (0.049)\ \text{Laying duck} \quad (5.3)$$

$$C\text{-emission}_{energy} = (1.157)\ \text{Swine} + (0.844)\ \text{Goat} + (0.026)\ \text{Three breed cross native chicken} + (0.049)\ \text{Pekin duck} + (0.031)\ \text{Laying duck} \quad (5.4)$$

Where:

$C\text{-input}_{livestock\ animal}$ = carbon mass emission from feed to animals by consumption of each animal in utilized age (ton carbon per year)

$C\text{-fixation}_{livestock\ animal}$ = carbon fixation in each animal body included egg (ton carbon per year)

$C\text{-emission}_{livestock\ animal}$ = total carbon emission from body of swine, goats, three breed-cross native chicken, pekin ducks and laying ducks (ton carbon per year)

$C\text{-emission}_{energy}$ = total carbon emission from body of swine, goats, three breed-cross native chicken, pekin ducks and laying ducks (ton carbon per year)

Swine = number of swine (individuals)

Goats = number of goats (individuals)

Three breed-cross native chicken = number of three breed-cross native chicken

Pekin ducks = number of pekin ducks (individuals)

Laying ducks = number of laying ducks (individuals)

Consequently, The Payoff Matrix Principle, Lapace's Rule and Maxi- mum Rule were applied to indicate the environmental impacts of livestock produc- tions. The results of this study recommend that the pork production create the lowest carbon emission among these livestock animals.

The carbon massflow of swine, goat, three breed-cross native chicken, pekin duck and laying duck productions could be shown in Figures 5.1-5.5.

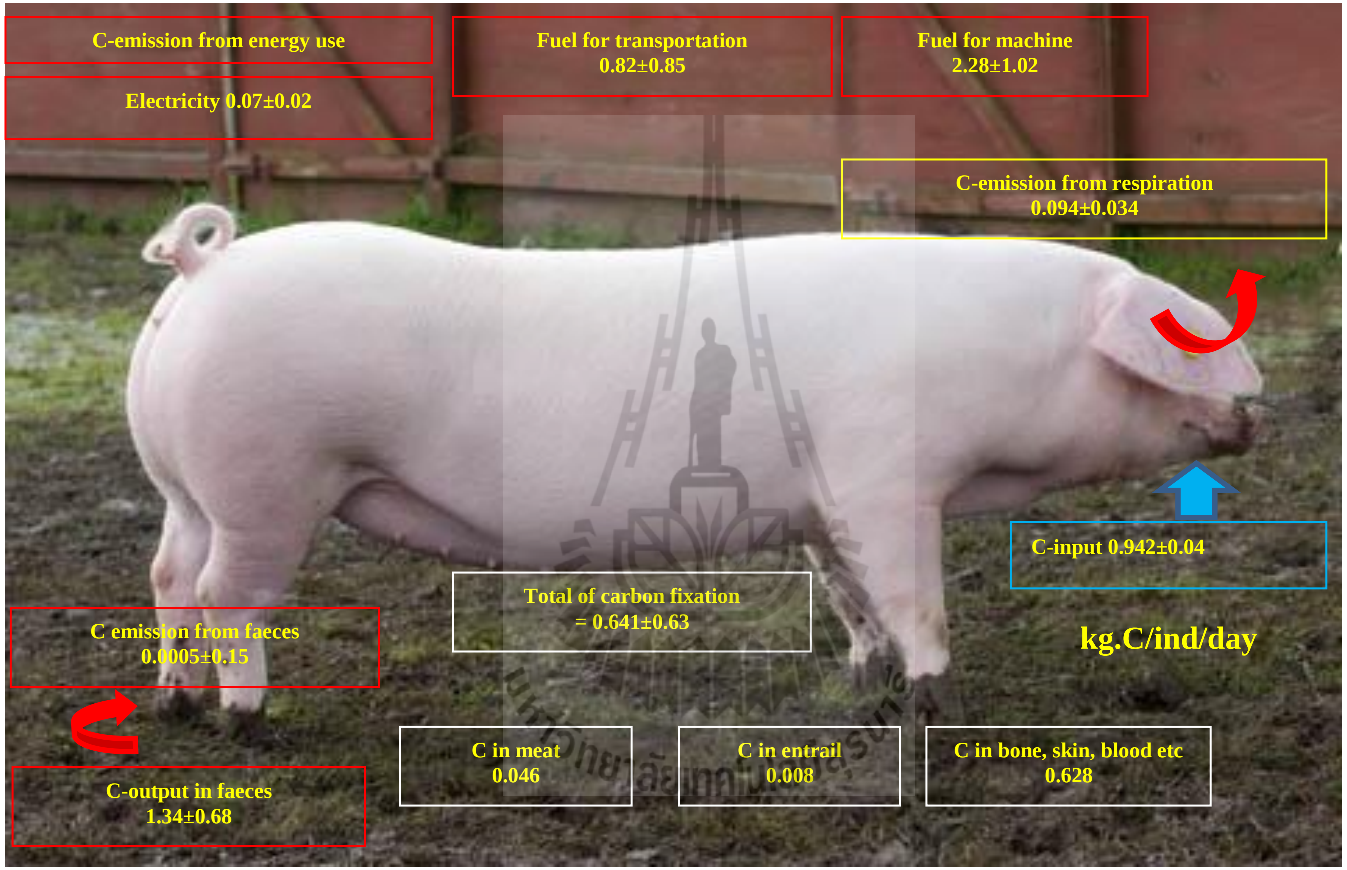


Figure 5.1 Diagram of carbon input, carbon fixation and carbon emission from swine production.

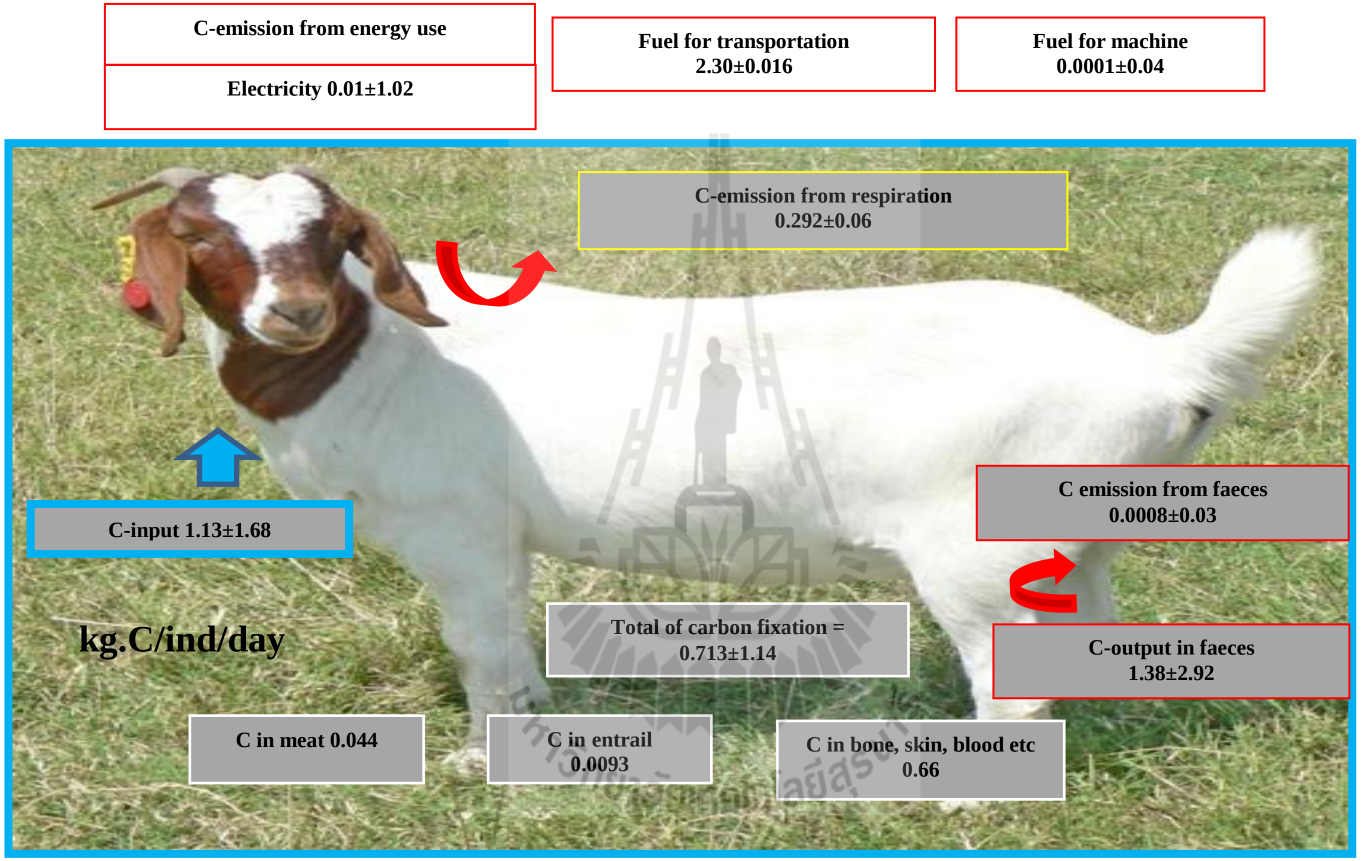


Figure 5.2 Diagram of carbon input, carbon fixation and carbon emission from goat production.

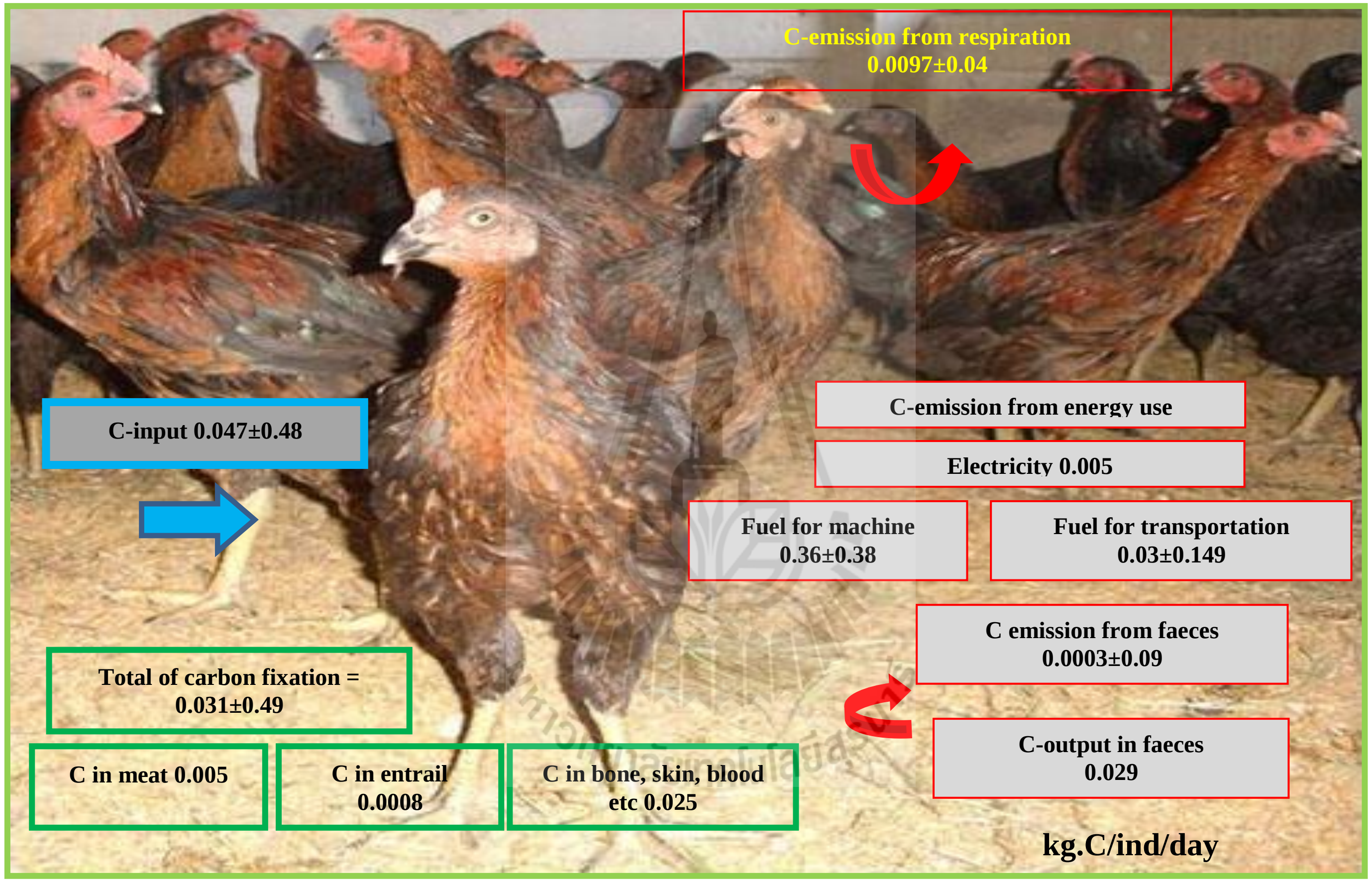


Figure 5.3 Diagram of carbon input, carbon fixation and carbon emission from three breed-cross native chicken production.

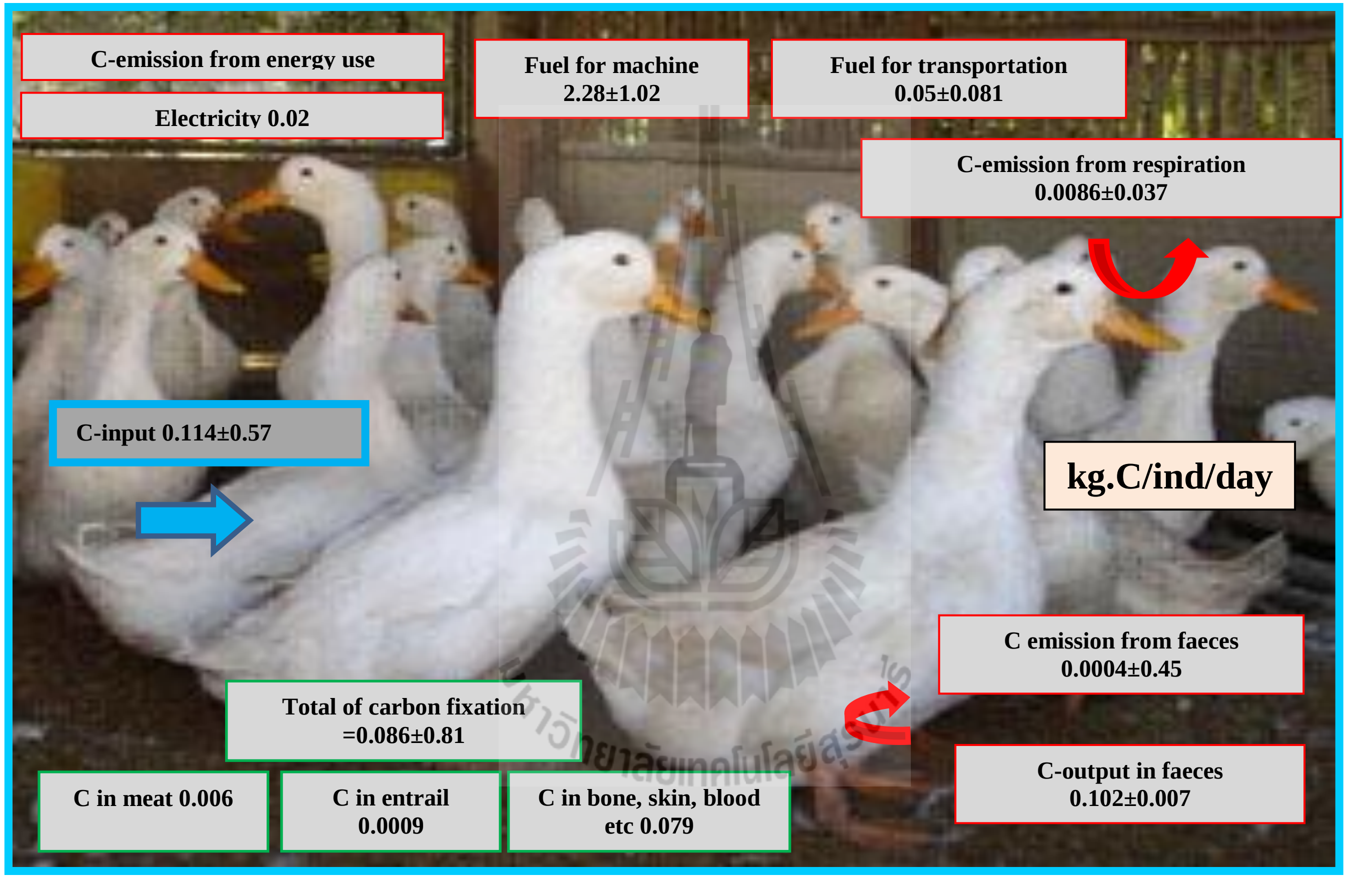


Figure 5.4 Diagram of carbon input, carbon fixation and carbon emission from pekin duck production.

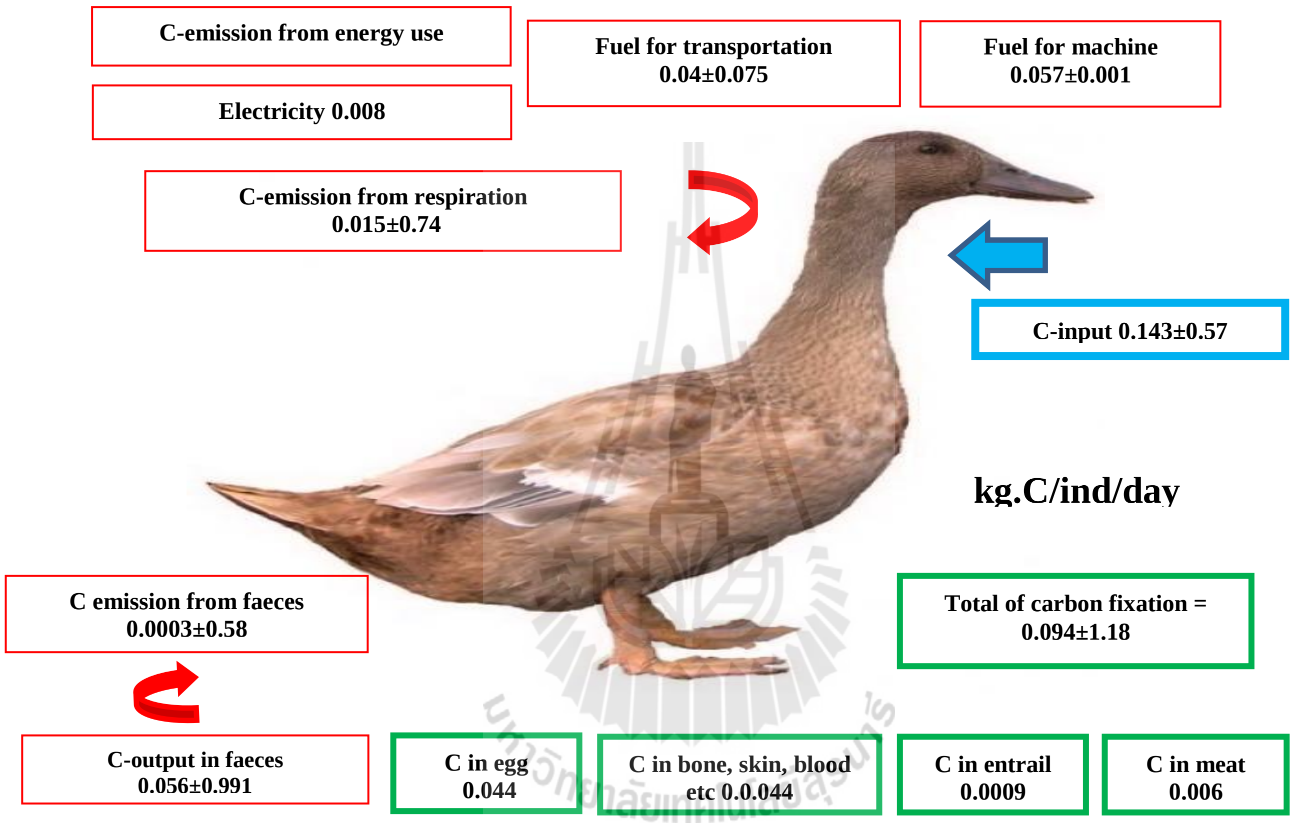


Figure 5.5 Diagram of carbon input, carbon fixation and carbon emission from laying duck production.

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APPENDICES

APPENDIX A

THE MULTIPLIER OF CARBON EMISSIONS FROM THE USE OF ELECTRICITY, FULE, 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 ($kg.CO_2$-eq/Unit)**	**Reference sources**
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
Biodiesels	L	2.6265	LPCC, 2007

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

Fuel type	Unit	Emission factor (kg.CO_2-eq/Unit)	Reference sources
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 lnformation Administration

Table A3 Emissions from electricity generation (g/k Wh).

Powern plant type		CO_2	NO_2	SO_2
commercial fuel	Cooking coal	322.80	1.80	3.40
	Fuel	258.50	0.88	1.70
	Natural gas	178.00	0.90	0.00
	Nuclear	7.80	0.00	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: Ability of fuel	Electricity production: Fuel density	Relationship between the reaction and products	C-input from electricity energy use	Amount of CO_2 (t)
Fuel oil 0.84%	11.05 kWh/L	Light oil at 15 ºC = 930 g/l	Fuel oil C_nH_{2n+2} (C=14-20)= (168/198) x (930/11.05)	0.0716 Kg.C_{C20H42}/kWh 0.0714 kg.C_{C14H30}/kWh	968,767
Diesel oil 0.24%	10.12 kWh/L	Diesel oil at 20 ºC = 850 g/l	Diesel oil ($C_{12}H_{26}$) = (144/170) x (850/10.12)	0.07111 kg.C_{C12H26}/kWh	50,904
Coking coal/ Lignite 19.28%	2.91 kWh/kg	Coking coal/Lignite** = %C 73% by weight	1g C_{CH14}=(2.9/667) x (16/12)	0.251 Kg.$C_{Lignite}$/KWh	17,717,652
Natural gas 66.90%	0.29 kWh/m^3	1 m^3 of CH_4 = 0.667 kg at standard condition (20 ºC 1 atm)	1 kg C_{CH14} =5.783 kWh	0.173 Kg.C_{CH14}/kWh	24,597,771
Biomass 1.90%	3.52 kWh/kg	biomass*** (bagases + 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 k Wh is equal to				0.158 Kg.C/kWh	0.5610 Kg.CO_2-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

QUESTIONNAIRE OF LIVESTOCK ANIMALS IN STUDY ON CARBON MASSFLOW OF SWINE, GOAT, THREE BREED-CROSS NATIVE CHICKEN, PEKIN DUCK AND LAYING DUCK PRODUCTIONS FOR CARBON FOOTPRINTS DEVELOPMENT IN NAKHON RATCHASIMA, PRACHIN BURI AND CHON BURI PROVINCES, THAILAND

Table B1 The questionnaire of swine.

No. ________ Name ____________________ Add ____________________ Date ______________Table of swine

Size of house (W XL)	Number of animal	Number of swine	C-input (Kg/livestock animal./day)		C-output from faeces (Kg/livestock animal./day)		C-output from energy used in farm (Kg/livestock animal./day)		C-output from transportation (Kg/livestock animal./day)			
			Type of feed	Feed in take (Kg/day) (Kg/mount)	Average weight of faeces (Kg/time)	Number of animal (Head/time)	Number of houses	Cost of electric/ month(Bath)	Cost of fuel (Bath/Time) (L/Time)	Weight of feed (Bag/Time) (Kg./Time)	Distance of feed (Km.)	Type of car

Chaff /Time (Kg/Tone)	Total of chaff (Kg/Tone)

Lamp	Number (Tube)	Watt (W)	Time on-off (hr/day)

The frequency of food transportation (Number of times) =

C-fixation (Kg/livestock animal./day)			
Weight in (Kg)	Time of duration (Day or Month)	Weight out (Kg)	Number of animal out (Head)

Type of energy used	Number (Kg./L.)	Time of used (Kg./L.)
LPG		
Diesel oil		

Pump	Number (Head)	Watt (W)	Time on-off (hr./day)

Fan	Number (Head)	Watt (W)	Time on-off (hr/day)

Empty trucks (Kg/ton)	Load of animal (Number or Kg.)	Distant of small swine (Km.)	Type of truck

Empty trucks (Kg/ton)	Load of swine (Number or Kg.)	Distant for swine transport (Km.)	Type of truck

Parent stock farm to farms Km.	Number-fed annually (Time/Year)
Farm to slaughterhouse or market Km.	
Water used on farms	The wastewater from the farm Wastewater Treatment ❍ Yes.______________ ❍ No.

Energy used in Slaughterhouse (fattening swine)				Energy used in Slaughterhouse (fattening swine)				
Lamp	Number (Tube)	Watt (W)	Time on-off (hr/day)	Pump	Number (Tube)	Watt (W)	Time on-off (hr/day)	Note:
Diesel oil	Number (L.)	Distance (Km)	Type of truck	Wood Chaff LPG	Number (Kg)	Number of ani. / Time / Month		

Table B2 The questionnaire of goat.

No. ________ Name ________________________ Add ____________________ Date ______________ Table of goat

			C-input (Kg/livestock animal./day)		C-output from faeces (Kg/livestock animal./day)		C-output from energy used in farm (Kg/livestock animal./day)		C-output from transportation (Kg/livestock animal./day)			
Size of house (W XL)	Number of animal	Number of goats	Type of feed	Feed in take (Kg/day) (Kg/mount)	Average weight of faeces (Kg/time)	Number of animal (Head/ time)	Number of houses	Cost of electric/ month(Bath)	Cost of fuel (Bath/Time) (L/Time)	Weight of feed (Bag/Time) (Kg./Time)	Distance of feed (Km.)	Type of car

Chaff /Time (Kg/Tone)	Total of chaff (Kg/Tone)

Lamp	Number (Tube)	Watt (W)	Time on-off (hr/day)

The frequency of food transportation (Number of times) =

C-fixation (Kg/livestock animal./day)			
Weight in (Kg)	Time of duration (Day or Month)	Weight out (Kg)	Number of animal out (Head)

Type of energy used	Number (Kg./L.)	Time of used (Kg./L.)
LPG		
Diesel oil		

Pump	Number (Head)	Watt (W)	Time on-off (hr./day)

Empty trucks (Kg/ton)	Load of animal (Number or Kg.)	Distant of small swine (Km.)	Type of truck

Parent stock farm to farms Km.	Number-fed annually (Time/Year)
Farm to slaughterhouse or market Km.	
Water used on farms	The wastewater from the farm Wastewater Treatment ❍ Yes.______________ ❍ No.

Fan	Number (Head)	Watt (W)	Time on-off (hr/day)

Empty trucks (Kg/ton)	Load of swine (Number or Kg.)	Distant for swine transport (Km.)	Type of truck

Energy used in Slaughterhouse (fattening swine)				Energy used in Slaughterhouse (fattening swine)				
Lamp	Number (Tube)	Watt (W)	Time on-off (hr/day)	Pump	Number (Tube)	Watt (W)	Time on-off (hr/day)	Note:
Diesel oil	Number (L.)	Distance (Km)	Type of truck	Wood Chaff LPG	Number (Kg)	Number of ani. / Time / Month		

Table B3 The questionnaire of three breed-cross native chicken.

No. __________ Name ______________________________ Add ___________________________ Date __________________ Table of TNC

Size of house (W XL)	Number of animal	Number of TNC	C-input (Kg/livestock animal./day)		C-output from faeces (Kg/livestock animal./day)		C-output from energy used in farm (Kg/livestock animal./day)		C-output from transportation (Kg/livestock animal./day)			
			Type of feed	Feed in take (Kg/day) (Kg/mount)	Average weight of faeces (Kg/time)	Number of animal (Head/ time)	Number of houses	Cost of electric/ month(Bath)	Cost of fuel (Bath/Time) (L/Time)	Weight of feed (Bag/Time) (Kg./Time)	Distance of feed (Km.)	Type of car
					Chaff /Time (Kg/Tone)	Total of chaff (Kg/Tone)			The frequency of food transportation (Number of times) =			

C-fixation (Kg/livestock animal./day)				Type of energy used	Number (Kg./L.)	Time of used (Kg./L.)
Weight in (Kg)	Time of duration (Day or Month)	Weight out (Kg)	Number of animal out (Head)	LPG		
				Diesel oil		

Lamp	Number (Tube)	Watt (W)	Time on-off (hr/day)
Pump	Number (Head)	Watt (W)	Time on-off (hr./day)
Fan	Number (Head)	Watt (W)	Time on-off (hr/day)

Empty trucks (Kg/ton)	Load of animal (Number or Kg.)	Distant of small swine (Km.)	Type of truck
Empty trucks (Kg/ton)	Load of swine (Number or Kg.)	Distant for swine transport (Km.)	Type of truck

Parent stock farm to farms Km.	Number-fed annually (Time/Year)
Farm to slaughterhouse or market Km.	
Water used on farms	The wastewater from the farm Wastewater Treatment ❍ Yes.________________ ❍ No.

Energy used in Slaughterhouse (fattening swine)				Energy used in Slaughterhouse (fattening swine)				
Lamp	Number (Tube)	Watt (W)	Time on-off (hr/day)	Pump	Number (Tube)	Watt (W)	Time on-off (hr/day)	Note:
Diesel oil	Number (L.)	Distance (Km)	Type of truck	Wood Chaff LPG	Number (Kg)	Number of ani. / Time / Month		

Table B4 The questionnaire of pekin duck.

No. _________ Name _______________________ Add ______________________ Date ________________ Table of pekin duck

Size of house (W XL)	Number of animal	Number of pekin ducks	C-input (Kg/livestock animal./day)		C-output from faeces (Kg/livestock animal./day)		C-output from energy used in farm (Kg/livestock animal./day)		C-output from transportation (Kg/livestock animal./day)			
			Type of feed	Feed in take (Kg/day) (Kg/mount)	Average weight of faeces (Kg/time)	Number of animal (Head/ time)	Number of houses	Cost of electric/ month(Bath)	Cost of fuel (Bath/Time) (L/Time)	Weight of feed (Bag/Time) (Kg./Time)	Distance of feed (Km.)	Type of car
					Chaff /Time (Kg/Tone)	Total of chaff (Kg/Tone)			The frequency of food transportation (Number of times) =			

C-fixation (Kg/livestock animal./day)			
Weight in (Kg)	Time of duration (Day or Month)	Weight out (Kg)	Number of animal out (Head)

Type of energy used	Number (Kg./L.)	Time of used (Kg./L.)
LPG		
Diesel oil		

	Number	Watt	Time on-off
Lamp	Number (Tube)	Watt (W)	Time on-off (hr/day)
Pump	Number (Head)	Watt (W)	Time on-off (hr./day)
Fan	Number (Head)	Watt (W)	Time on-off (hr/day)

Empty trucks (Kg/ton)	Load of animal (Number or Kg.)	Distant of small swine (Km.)	Type of truck
Empty trucks (Kg/ton)	Load of swine (Number or Kg.)	Distant for swine transport (Km.)	Type of truck

Parent stock farm to farms Km.	Number-fed annually (Time/Year)
Farm to slaughterhouse or market Km.	
Water used on farms	The wastewater from the farm Wastewater Treatment ❍ Yes.______________ ❍ No.

Energy used in Slaughterhouse (fattening swine)				Energy used in Slaughterhouse (fattening swine)				
Lamp	Number (Tube)	Watt (W)	Time on-off (hr/day)	Pump	Number (Tube)	Watt (W)	Time on-off (hr/day)	Note:
Diesel oil	Number (L.)	Distance (Km)	Type of truck	Wood Chaff LPG	Number (Kg)	Number of ani. / Time / Month		

Table B5 The questionnaire of laying duck.

No. _________ Name ________________________ Add _______________________ Date ________________ Table of laying duck

Size of house (W XL)	Number of animal	Number of laying ducks	C-input (Kg/livestock animal./day)		C-output from faeces (Kg/livestock animal./day)		C-output from energy used in farm (Kg/livestock animal./day)		C-output from transportation (Kg/livestock animal./day)			
			Type of feed	Feed in take (Kg/day) (Kg/mount)	Average weight of faeces (Kg/time)	Number of animal (Head/ time)	Number of houses	Cost of electric/ month(Bath)	Cost of fuel (Bath/Time) (L/Time)	Weight of feed (Bag/Time) (Kg./Time)	Distance of feed (Km.)	Type of car

Chaff /Time (Kg/Tone)	Total of chaff (Kg/Tone)

Lamp	Number (Tube)	Watt (W)	Time on-off (hr/day)

The frequency of food transportation (Number of times) =

C-fixation (Kg/livestock animal./day)			
Weight in (Kg)	Time of duration (Day or Month)	Weight out (Kg)	Number of animal out (Head)

Type of energy used	Number (Kg./L.)	Time of used (Kg./L.)
LPG		
Diesel oil		

Pump	Number (Head)	Watt (W)	Time on-off (hr./day)

Empty trucks (Kg/ton)	Load of animal (Number or Kg.)	Distant of small swine (Km.)	Type of truck

Fan	Number (Head)	Watt (W)	Time on-off (hr/day)

Empty trucks (Kg/ton)	Load of swine (Number or Kg.)	Distant for swine transport (Km.)	Type of truck

Parent stock farm to farms Km.	Number-fed annually (Time/Year)
Farm to slaughterhouse or market Km.	
Water used on farms	The wastewater from the farm Wastewater Treatment ❍ Yes.________________ ❍ No.

Energy used in Slaughterhouse (fattening swine)				Energy used in Slaughterhouse (fattening swine)				
Lamp	Number (Tube)	Watt (W)	Time on-off (hr/day)	Pump	Number (Tube)	Watt (W)	Time on-off (hr/day)	Note:
Diesel oil	Number (L.)	Distance (Km)	Type of truck	Wood Chaff LPG	Number (Kg)	Number of ani. / Time / Month		

APPENDIX C

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 animal feed, livestock meat productions and faeces (Figure C1). Prior to carbon analysis, samples are oven dried at 103-105 ºC 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 950-1050 ºC 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 C1 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 ºC; 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 (Figure C2).

The CHN analyzers are calibrated with EDTA substance that indicates the percentage of carbon, hydrogen and nitrogen were 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 950-1050 ºC with a constant flow of pure oxygen. Click "Configuration" from the File menu and select "Drift"; EDTA capsule is released into the furnace l capsule per time.

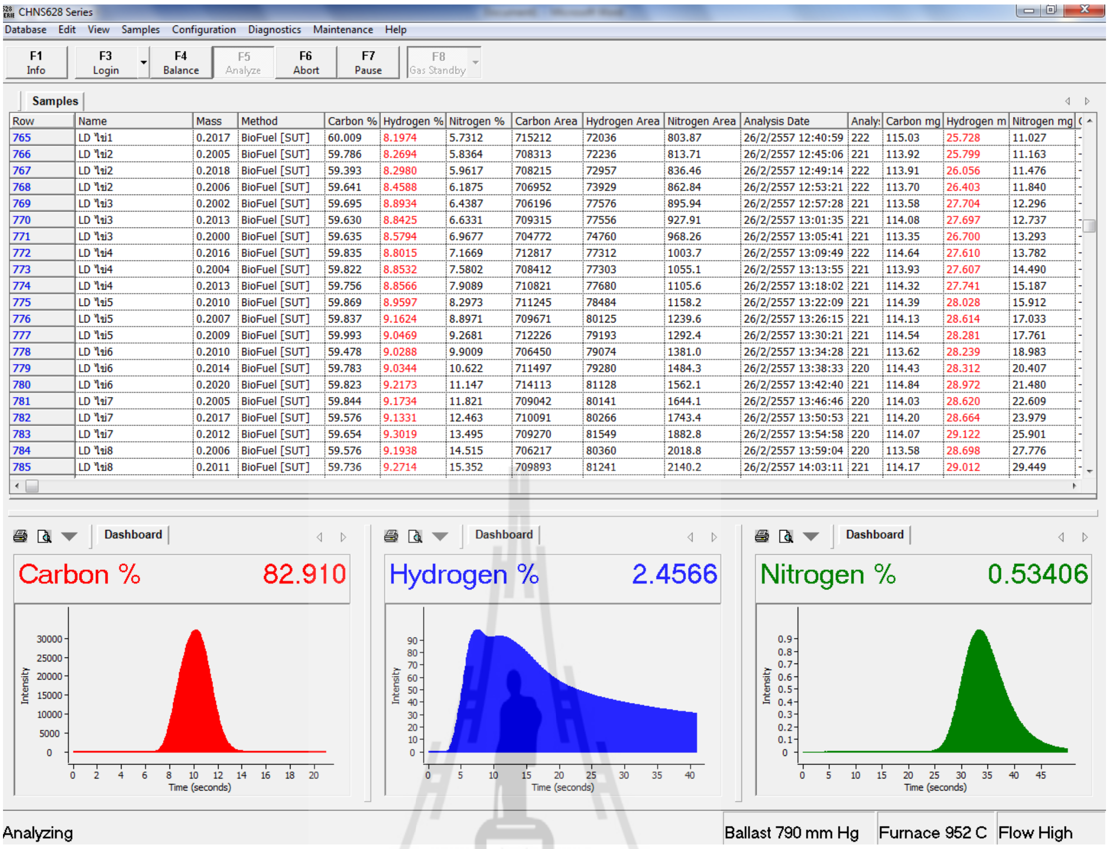

Figure C2 The main window displays of the LECO CHN628 Series Elemental Analyzer and CHN628 series parameters.

Analysis carbon emission in the form of CO_2 and CH_4 from the digestion and respiration of animal livestock and faeces measured by Gas Analyzer.

Figure C3 The measuring CO_2 and CH_4 of livestock animal faeces and CO_2 and CH_4 from respiration and digestion.

APPENDIX D

PUBLICATIONS

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Carbon Footprint from Meat Production of Thai Cross Breed Native Chicken in Nakhon Ratchasima Province, Thailand

Panisara Vichairattanatragul, Prayong Keeratiurai, and Nathawut Thanee

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Abstract—Poultry production in Thailand has been increased in the past years. Species of chicken have been genetically developed for commercialization. Thai cross breed native chickens are the cross breeds of Thai male indigenous fighting cocks and female broilers. The objectives of this research were to compare carbon massflow and carbon footprint of Thai cross breed native chicken production between a state farm and private farms in Nakhon Ratchasima province, Thailand. The results revealed that carbon input (C-input) were 1.030±0.032 and 1.049±0.026 kg.C/individual/day, carbon fixation (C-fixation) were 0.853±0.013 and 0.868±0.034 kg.C/individual/day, and carbon output (C-output) were 0.180±0.006 and 0.181±0.037 kg.C/individual/day, respectively. The carbon footprint (CFP) of Thai cross breed native chicken were 0.760±0.054 kg.$C0_2$.eq./1 kg.individual and 0.7741±0.056 kg.$C0_2$.eq./1 kg.individual, respectively. Furthermore, the carbon footprint of Thai cross breed native chicken in Nakhon Ratchasima provience from the use of energy was 15.123 kg.$C0_2$.eq./1 kg.individual, individual Thai cross breed native chicken was 0.767 kg.$C0_2$.eq./1 kg.individual. It can be concluded from the findings that the carbon footprints (CFP) are almost from the energy use in transportation, it should be the first consideration to reduce energy use in chicken production.

Keywords—carbon emission, carbon footprint, Nakhon Ratchasima, Thai cross breed native chicken

I. INTRODUCTION

CLIMATE changes are mainly caused by the greenhouse gases released from human activities and other sources to the atmosphere. The livestock production is included into one of the major sources of air pollution, especially carbon dioxide (CO_2), methane (CH_4) and nitrogen oxides (NO_x) [1, 2]. Livestock animals meet a variety of food needs for people [3]. Therefore, the poultry production in Thailand has been increased in the past years. Species of chicken have been genetically developed for commercialization [4, 5] and Thai cross breed native chicken are the cross breeds of Thai male indigenous fighting cocks and female broilers. In general, they are the so-called Gai Baan Thai, meaning Thai domestic chicken. Among Thai consumers, meat of the Thai cross breed native chicken is more preferable and recognized as lean, tasty, not so tough and chewy, and has higher economic values compared to commercial broiler meat [7]. Gai Baan Thai are promoted as a commercial product for exporting and the Livestock Development Department and the Exporting Promotion Department have been working closely to develop the breeds with higher meat quality. Although, the livestock productions meet the requirement of government sectors, private sectors, and farmers, the environmental impact from the production should be considered [7, 8, 4]. Therefore, Thailand has attempted to be the leadership in trade of livestock production exports to the ASEAN Economic Community (AEC). Thailand needs to investigate the basic data of carbon massflow and carbon footprint of the livestock production as well as to develop the process in achieving the least environmental impact [2, 9 -13]. The aim of the present work focused on Thai cross breed chicken 8-10 weeks of age or 1.0-1.2 kg. body weight to prepare as raw materials for grilled chicken.

II. MATERIALS AND METHODS

A. Study Site

Based on the data obtained from the Agricultural Information Center, Office of Agricultural Economics, Nakhon Ratchasima was the selected province, which represented the production of native Thai cross breed chicken [14]. This province is the largest area and provides many Thai cross breed chicken farms as shown in the distribution of production areas within Thailand (Fig. 1A) and the province of Nakhon Ratchasima (Fig. 1B) [15].

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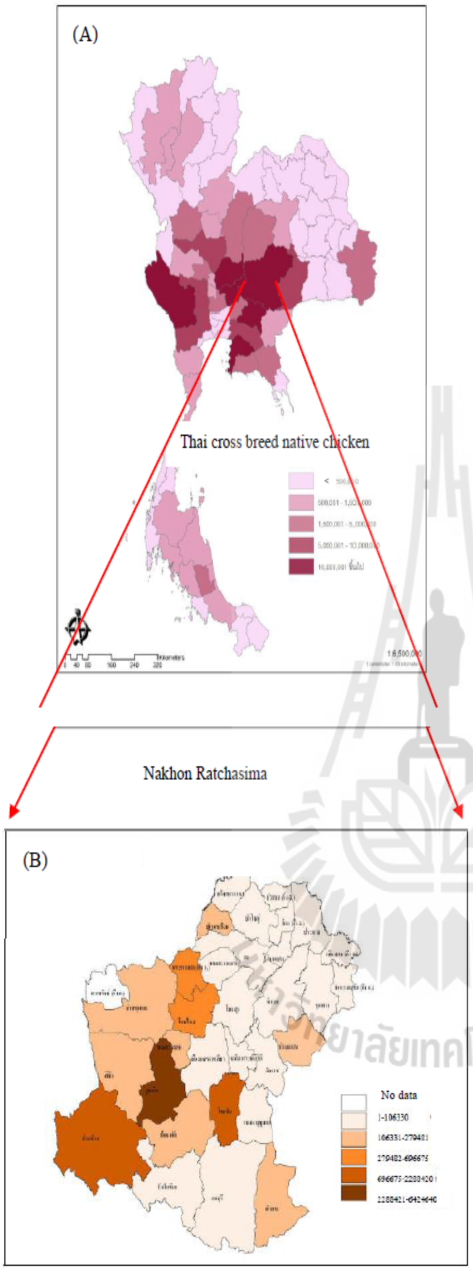

Fig. 1 Density number of Thai cross breed native chicken in Thailand (A) and in Nakhon Ratchasima province (B)

B. Size of Samples

The formula of Taro Yamane was applied to calculate the number of farms and Thai cross breed native chicken in Nakhon Ratchasima province [15]. The formula is:

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

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

For example, the sample size of Thai cross breed native chicken farms in Nakhon Ratchasima province for the study was calculated according to the recommendation as follow:

$n = 2437/[1+2437x(0.05)^2] = 344$ Thai cross breed native chicken farms

At 95% confident level, the number of studied Thai cross breed native chicken farms were 344 farms and 344 Thai cross breed native chicken in Nakhon Ratchasima province. Animal feed, cross native chicken and faeces samples were collected from state and private farms and transferred to the laboratory at Suranaree University of Technology. CO_2 was detected by Gas Analyzer from living cross native chicken at the farms [9, 3]. Percentage of moisture, and carbon content were analyzed following the methods of Manlay et al. [16-18], while the volatile solid, fixed solid and weight were investigated by the techniques of APHA, AWWA, WEF, [19, 20].

III. RESULTS

III. RESULTS

The carbon content as the unit of kilogramme carbon per kilogramme of chicken weight per day (kg.C/individual/day) was used to study the carbon massflow from animal feed to the biomass of Thai cross breed native chicken (C-input). The carbon transference and fixation rates were determined from the state and private farms in Nakhon Ratchasima province. The rate of carbon transference from animal feed to Thai cross breed chicken for state and private farms were 1.030±0.032 and 1.049±0.026 kg.C/individual/day, respectively. Carbon fixation of Thai cross breed chicken were 0.853±0.013 and 0.868±0.03 kg.C/individual/day, respectively. The C-output minus the carbon contents emitted in faeces, enteric fermentation, and respiration (C-emission) was the carbon mass fixed in the body (C-fixation). The carbon emission for the two groups were 0.180±0.006 and 0.181±0.037 kg.C/individual/day, respectively. These results are summarized in Tables 1 and 2. The value of carbon massflow C-input, C-output and C-emission between state and private farms were not significantly different ($P \leq 0.05$). The results revealed that the carbon massflow were different from Thanee et al. [3], while the values of young layer production was not significantly different ($P \leq 0.05$).

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TABLE I
COMPARISON OF CARBON INPUT, CARBON FIXATION AND CARBON EMISSION OF THAI CROSS BREED NATIVE CHICKEN BETWEEN STATE AND PRIVATE FARMS IN NAKHON RATCHASIMA PROVINCE; MEAN±S.D

Parameters	State farm	Private farms
C_{input} (kg.C/individual/day)	1.030±0.032	1.049±0.026
$C_{fixation}$ (kg.C/individual/day)	0.853±0.013	0.868±0.034
$C_{emission}$ (kg.C/individual/day)	0.180±0.006	0.181±0.037
$C_{emission}/C_{input}$(%)	17.51	17.28
$C_{emission}/C_{fixation}$(%)	21.14	20.88
Fixation efficiency, C = (C_{input} - $C_{emission}$)/C_{input} (%)	82.49	82.72

TABLE II
CARBON EMISSION PER INDIVIDUAL PER DAY AND CARBON EMISSION PER DAY COMPARING FROM SAME WEIGHT OF ANIMAL; MEAN ± S.D.

Animal	Fresh faeces wt (kg./ind/day)	% Faeces per ind. wieght	Carbon emission (kg.C/ind/day)	Mean live animal weight in farm (kg./ind)	Carbon emission comparing from same weight (kg.C/kgind.wt/day) x 10^{-3}
State farm	0.080 ± 0.41	3.32	0.180□0.006	1.24 ± 0.05	14.60□0.005
Private farms	0.067 ± 0.37	3.54	0.181□0.037	1.39 ± 0.63	13.02□0.040

The carbon footprint (CFP) of Thai cross breed native chicken both from state and private farms was 15.883 kg.CO_2.eq./1 kg.individual. Most carbon footprint from energy was 15.123 kg.CO_2.eq./1 kg.individual but carbon footprint form faeces and respiration was 0.767 kg.CO_2.eq./1 kg.individual (Fig. 2). The results showed that the carbon footprint (CPF) was the highest in the use of energy especially during the transportation of the production as shown in Table 3. Then the farmers should develop and manage the use of energy in Thai cross breed native chicken.

TABLE III
RATIO OF CARBON EMISSION FROM LIVESTOCK AND ENERGY USE OF FARMS AND SLAUGHTERHOUSES IN THAI CROSS BREED NATIVE CHICKEN MEAT PRODUCTION

Ratio of carbon emitted form	State farm	Private farms
Animal (%)	3.63	7.39
Energy use (%)	96.47	92.71

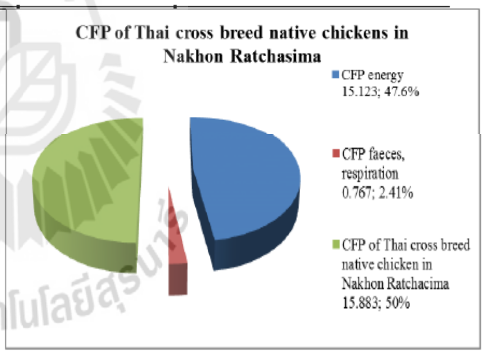

Fig. 2 The composition of CFP in the production of Thai cross breed native chicken in Nakhon Ratchasima province

The carbon footprints (CFP) of meat production of Thai cross breed native chicken of state and private farms were 0.760 and 0.774 kg.CO_2.eq./1 individual, respectively which were not different ($P \leq 0.05$). However, the carbon footprint of state farm and private farms in the use of energy were 20.580 and 9.536 kg.CO_2.eq./1 kg.chicken, respectively and the values differed significantly ($P \leq 0.05$) as shown in Fig. 3 This result was similar to Thanee and Keeratiurai [22], who found that the carbon footprint of commercial broiler meat production and private company Thai cross breed native meat production were not significantly different ($P \leq 0.05$).

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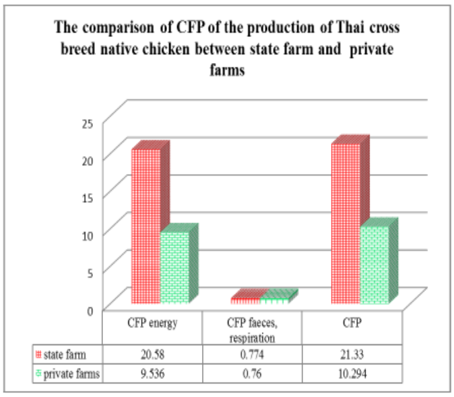

Fig. 3 The comparison of CFP of the production of Thai cross breed native chicken between state and private farms

The production of Thai cross breed native chicken of state farm should increase the number of animal per experiment to reduce the carbon footprint especially in the use of energy. In particular, the Department of Livestock Development has to promote the production process of Thai cross breed native chicken to farmers. Moreover, they should expand the markets and provide useful information to the farmers, especially, for exporting this product to the ASEAN Economic Community (AEC). For the reduction of the carbon footprint, The effective way to reduce the use of energy is to reduce the transportation distance of chicken food. In addition, Thailand aims to be the leader in the trade of livestock production exports within the ASEAN Economic Community (AEC). Therefore, the Thailand government should put a research programme into place to investigate and quantify carbon massflow of the livestock productions and to develop a process to measure and minimize the environmental impacts.

IV. DISCUSSION

The carbon massflow of Thai cross breed native chickens between of state and private farms showed that carbon input (C-input) were 1.0298±0.032 and 1.0487±0.026 kg.C/individual/day, carbon fixation (C-fixation) were 0.8531±0.013 and 0.8678±0.034 kg.C/individual/day, and carbon output (C-output) were 0.1803±0.006 and 0.1812±0.037 kg.C/individual/day, respectively. The values of carbon massflow of Thai cross breed native chicken between state and private farms were not significantly different ($P \leq 0.05$). The carbon footprints (CFP) of Thai cross breed native chicken of state and private farms were 0.760 kg.CO_2.eq./1 kg.individual and 0.774 kg.CO_2.eq./1 kg.individual, respectively. Furthermore, the carbon footprint from the use of energy were 20.580 kg.CO_2.eq./1 kg.individual and 9.536 kg.CO_2.eq./1 kg.individual. It can be concluded that the carbon footprints (CFP) are almost from the transportation, so it should be considered to reduce of the energy in the production.

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ASSESSMENT OF THE CARBON MASSFLOW FROM THE LAYER FARMING WITH LIFE CYCLE INVENTORY

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ABSTRACT

Life cycle inventory is a useful tool for estimating carbon mass of the food support eating. Layers were energy using animals that were raised for their egg, and produced emissions of green house gasses such as CO_2 and CH_4. Therefore it was important to study and understand the relationship between the carbon emissions and carbon mass transfer for egg production. This case study of egg production were studied to evaluate carbon emission on layer farms, to investigate the rate of carbon massflow from layer feed to layers and egg in farms and to study the carbon emission in energy patterns from electric energy and petrol used in egg production. The study showed that the weight measurements of layer on farms found that a layer was 1.91 ± 0.15 kg/head at 400.63 ± 109.72 days. The egg weight measurements of layer on farms found was 0.047 ± 0.009 kg/head/day. The study also showed that the carbon emitted per unit from a layer of the young chicken farms and layer farms in Khon Kaen and Nakhon Nayok provinces were 0.004 ± 0.003 and 0.006 ± 0.003 kg.C/individual/day, respectively and the carbon emission from the using of transportation energy was 94.29 %, the carbon emission from the using of electricity energy and the carbon emission from the using of LPG was 2.86 % and 2.86 %, respectively. The productive carbon footprint of 1 kg of egg was 5.612 kg.CO_2.equivalent. The carbon fixation in eggs was 0.013 ± 0.003 kg.C/individual/day, and the rate of carbon massflow from layer feed (C_{input}) of Khon Kaen and Nakhon Nayok provinces were 0.027 ± 0.004 and 0.042 ± 0.004 kg.C / individual / day, respectively. The ratio of total carbon emitted per unit to total carbon contents per unit in layer feed ($C_{emitted}$ / C_{input}) of Khon Kaen and Nakhon Nayok provinces were 14.80 and 14.29, respectively. The ratio of total carbon emitted per day to carbon fixation per day in layers ($C_{emitted}$ / $C_{fixation}$) of Khon Kaen and Nakhon Nayok provinces were 17.39 and 16.67, respectively. The carbon emission from the using of transportation energy was quite high in terms of energy using but low in the using of electricity and LPG activities. Therefore, farmers should reduce emissions from energy consumption such as reduce electricity utilization in layer farming and reduce distance for layer feed and layers transportation to farms. The using of fuel for transportation should be reduced because it creates the highest carbon emission. The result of this study also showed that the average egg weight was 62.8 ± 4.45 g. / egg and 308.11 eggs / head at 80 weeks old of layer. The relation between the average egg weight (g) and phase out of egg laying (weeks) was the average egg weight in gram = 5.4368 * Ln * (phase out of egg laying in weeks) + 44.935 at R^2 = 0.8388. The layer had the highest percentage of the rate of egg laying in range 84 - 86 % at 27 - 28 degree Celsius. The relation between the rate of egg laying (%) and temperature (°C) was the percentage of rate of egg laying = 1.5605 * (temperature in °C)^4 -172.2 * (temperature in °C)^3+7117.6 * (temperature in °C)^2-130611 * (temperature in °C) + 897897 at R^2 = 0.1631.

Keywords: carbon, egg, layer, life cycle inventory.

INTRODUCTION

The importantly economic livestocks have been produced in many areas of Thailand especially pigs, broilers and layers. During the years 2545-2551 (B.E.), pig and layer productions had been increasing which layer production was higher than pig production. Whereas, broiler production had been decreased gradually as shown in Figure-1. Most layer broilers were raised in Nakhon Nayok, Khon Kaen and Chachoengsoa (Department of Livestock Development, 2009). The food production system as a whole is recognized as one of the major contributors to environmental impacts since it is a great consumer of both energy and natural resources.

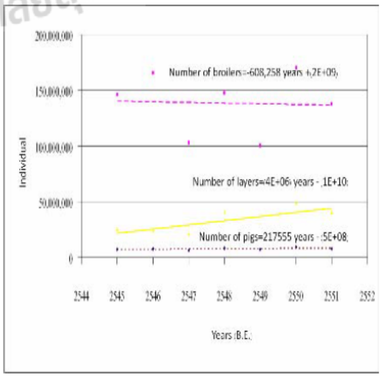

Figure-1. Tendency of pig, broiler and layer productions.

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The current consumption pattern has motivated an increasing interest to report the environmental performance of food products. In this sense, the food production, processing, transport and consumption account for a relevant portion of the environmental greenhouse gas (GHG) emissions. The emissions from food production have increase for two main reasons. First, a growing world population demands more food. Secondly, changes in dietary preferences towards higher-order foods can be increase GHG emissions, with trends towards more intensive of egg production. A growing demand for egg production requires the greater use of the demand for energy. It also induces changes in land use: a process that inevitably leads to CO_2 emissions into the atmosphere. Food production and food consumption are consequently of critical importance in the current and future development of GHG emissions. One of the environmental threats that our planet faces today is the long-term change in Earth's climate and temperature patterns due to global climate change, or the greenhouse effect. CO_2 and CH_4 from human activities are the most important greenhouse gases contributing to global climate change (IPCC, 1995) with CH_4 being 23 times more potent than CO_2 (IPCC, 1996). Chicken and layer are energy-using animals that are raised for their meat and egg, and produce emissions of both CO_2 and CH_4. Carbon is an important element for humans because it is the primary element of both plants and animals and it cycles through living and non-living components. The growth rates of human population drivers the demand of livestock production increase. Livestock animals meet a variety of food needs for people (Thornton *et al*., 2009). They are important nutrient sources of protein in the form of meat and egg (Lauhajinda, 2006). Livestock productions have emitted some greenhouse gases from fertilization, feed production, transportation, energy use in housing, respiration and digestion of livestock (Thanee *et al*., 2009a). The effects of livestock productions due to the utilization and changes of natural resources and environmental factors on the global should be considered (IPCC, 1996). The productive processes should release the least greenhouse gases to avoid such problems and save the Earth. Life cycle inventory (LCI) is an environmental assessment tool for evaluating the impacts that a product has on the environment over the entire period of its life from the raw materials extraction which it was made through the manufacturing, packaging processes, and the use, reuse and maintenance of the product and on to its eventual recycling or disposal as waste at the end of the useful life (Thu Lan and Shabbir, 2008). Layers are energy using animals that are raised for their meat and egg, and produce emissions of CO_2. The carbon emission is an alternative for consumers to select the products that release greenhouse gases emission into the environment (Thanee, Dankitikul and Keeratiurai, 2009b). The net carbon production is the rate at which carbon is fixed during growth and laying eggs, and can be used to explain the time averaged C stocks by carbon weight per time (van Noordwijk and Cerri, *et al*., 1997, van Noordwijk and Murdiyarso *et al*., 1998). Therefore, it is important to study the relevant factors concerning the entire production both physical and biotic environment (Thanee and Keeratiurai, 2010). This study deals with the assessment of the carbon emission for egg products which focused on carbon transferred to food chain and fixed in layer meat and eggs. In particular, the estimation of the rate of carbon massflow from animal feed to layer, and including the carbon emissions from electricity, petroleum, and LPG used during egg production were studied in Thailand.

MATERIALS AND METHODS

Study area

Khon Kaen and Nakhon Nayok provinces were selected which represent egg production of Thailand were based on the data of Agricultural Information Center, Office of Agricultural Economics (2004). These provinces have large areas and provide many layer farms and egg productions in these areas as shown in Figure-2 (Department of Livestock Development, 2009).

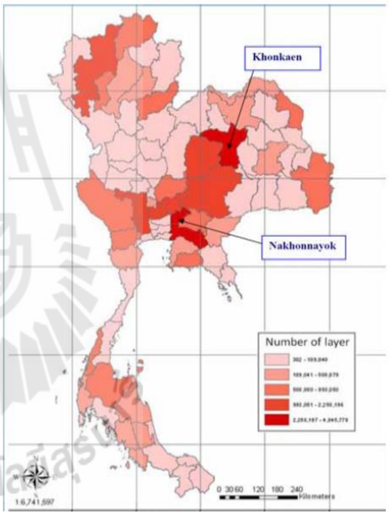

Figure-2. The study of the layer farming area in Khonkaen and Nakhonnayok provinces of Thailand. (From http://www.dld.go.th/index.html, department livestock Development, 2009).

LCI methodology applied in this study

Life cycle inventory analysis involves data collection and calculation procedures to quantify the relevant input and outputs of a product system. These inputs and outputs may include the use of resources and releases pollutant to air, water and land associated with the system (Thu Lan, 2007). Life cycle study, data collection represented a time consuming task and it was important to obtain quantitative information concerning various processes in the product system. A significant part of data associated with life cycle of egg production was collected from chick and layer farms. Data for energy consumption,

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resources and material were obtained directly from farms. A useful instrument facilitating the estimation of gas emissions was the emission factor, which was a representative value attempts to link the associate with the system output. The process of impact assessment analyzes the environmental burdens associated with the material and energy flows determined in the inventory analysis phase though successive steps listed as follow classification, characterization, normalization and weighting (Curran, 1996).

Site sampling and analytical methods

The numbers of farms, young chickens, and layers in each district of selected provinces were calculated by determining the numbers of farms young chickens, and layers in the Khonkaen and Nakhonnayok provinces at 95% confidence level (Yamane, 1973; Cavana *et al*., 2001). (According to the population of the study, the totals of population study of the tender young chicken farms*, and layer farms were 2039*, and 1383, respectively). Therefore, the sample groups were calculated by Taro Yamane's formula (Yamane, 1973) as follows:

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

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

So, the example of the sample size of chick farms for the study has been calculated according to the recommendation as follows:

$n = 2039 / \{1+2039*(0.05)^2\} = 335$ chick farms

With N = 2039, e = 5% (at 95% confidence level), hence the sample size is 335 respondents. The results showed that sample size were 335 young chicken farms, 400 young chickens and 311 layer farms, 400 layers calculated by *Taro Yamane* formula. Animal feed plus their egg and faeces were collected and transferred to the laboratory at Suranaree University of Technology for measurements. Carbon dioxide was measured from living layers at the farms. The evaluation of carbon emission from energy sectors in egg production was calculated with the software of Department of Livestock Development as shown in Figure-3 and the analytical methods are as follows:

a) Moisture contents were measured by weighing sample after oven drying at 103-105°C for 24 hours (APHA, AWWA and WEF., 1992).
b) Carbon contents were measured by CNS-2000 Elemental Analyzer (Manlay *et al*., 2004 b, and Keeratiurai and Thanee, 2013).
c) CO_2 was detected by Gas Analyzer (Kawashima, Terada and Shibata, 2000, and Keeratiurai and Thanee, 2013).
d) Volatile solids and ash were analyzed by weighing the known weight of the sample after burning at 550°C for 30 minutes (APHA, AWWA and WEF., 1992).
e) Weight of layer and egg by weighing (Vudhipanee *et al*., 2002, and Keeratiurai and Thanee, 2013).

(a) The software was used to calculate the carbon massflow from animal feed and carbon emission in energy sectors of the tender young chicken farms and layer farms in egg production.

(b) The software was used to calculate the carbon emission in energy sectors of the layer farms and the results of carbon massflow, emission, and footprint in egg production.

Figure-3. The software was used to calculate the carbon massflow, carbon emission in energy sectors, and carbon footprint in egg production.

RESULTS AND DISCUSSIONS

Life cycle inventory analysis

The result of this study showed that the carbon emission from egg production had 2 stages. The first stage before lay that was the feeding times until the tender young chickens were about 18 weeks old. The second stage was the egg laying that has egg about 2-3 years. With that in each period of stages would be the carbon

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emission from energy using was similar such as the electricity and LPG used on the farms and oil used in transportation.

The weight measurements of layer on farms found that a layer was 1.91±0.15 kg/head at 400.63±109.72 days. The egg weight measurements of layer on farms found was 0.047±0.009 kg/head/day. The study of life cycle inventory to evaluate the total carbon emission for the egg production in Khonkaen and Nakhonnayok, Thailand was shown in Figure-4.

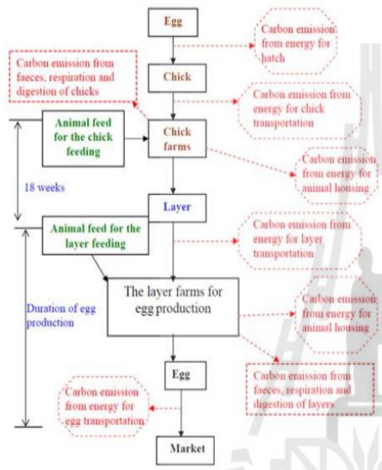

Figure-4. Scope of study on carbon emission from egg production.

Amount of carbon emission and rates of carbon input from layers

The carbon weights in the unit of kilogram carbon per kilogram of animal weight per day (kg.C/kg anim. wt/day) were used to study of carbon massflow from animal feed for feeding to the biomass of layer (C-input). The rate of carbon transference from animal feed for feeding in Khon Kaen and Nakhon Nayok provinces were 0.027±0.004 and 0.042±0.004 kg.C/ind./day, respectively. Carbon fixation was calculated by mass balance. The C-input minus the carbon contents emitted in faeces, enteric fermentation, and respiration (C-emitted) was the carbon mass fixed in the body (C-fixation). The carbon fixation of layer in Khon Kaen and Nakhon Nayok provinces were 0.023±0.004 and 0.036±0.004 kg.C/ind./day, respectively. The carbon emitted from faeces, enteric fermentation, and respiration in Khon Kaen and Nakhon Nayok provinces were 0.004±0.003 and 0.006±0.003 kg.C/ind/day, respectively as shown in Table-1.

A layer had carbon emission at 0.016±0.003 kg.C/kg.ind./day. Most carbon content was in the form of layer faeces at 87.88% of total carbon emission. Carbon content in the form of CO_2 and CH_4 from respiration and digestion of layers was at 11.93% of all total carbon emission.

Table-1. Rates of carbon input, carbon fixation and carbon emission of layer (mean ± S.D.).

Province	Khon Kaen	Nakhon Nayok
C_{input} (kg.C/ind./day)	0.027±0.004	0.042±0.004
$C_{fixation}$ (kg.C/ind/day)	0.023±0.004	0.036±0.004
$C_{emitted}$ (kg.C/ind/day)	0.004 ±0.003	0.006 ±0.003
$C_{emitted}$ /C_{input} (%)	14.80	14.29
$C_{emitted}$ /$C_{fixation}$ (%)	17.39	16.67
Fixation efficiency C = (C_{input} -$C_{emitted}$)/C_{input} (%)	85.19	85.71

The emission of carbon by mass conservation principle which could tell total carbon emission from animal in unit that was ton of carbon per year. The study showed that the rate of total carbon input from food plants to layer by consumption and then fixed in layer bodies, organs, faeces and eggs during rearing duration was shown in Table-2.

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Table-2. Average of carbon input (C_{plant}) fixed in layers ($C_{fixation}$) emitted from layers ($C_{emitted}$) in faeces (C_{output}) and C-emitted of CO_2 and CH_4 from respiration and digestion (mean ± S.D).

Amount C transferred from plant food to animal (kg.C/ind/day)			0.042 ± 0.010
Carbon fixation (kg.C/ind/day)	Total C-fixation		0.026 ± 0.007
	Egg		0.013 ± 0.003
	Total C accumulated in body (mass Equilibrium)		0.013 ± 0.004
Carbon emitted (kg.C/ind/day)	Total C-emitted from animal		0.016 ± 0.003
	Dry faeces		0.014 ± 0.003
	C -emission of CO_2 and CH_4	faeces	0.00003 ± 0.00001
		Digestion and respiration	0.0019 ± 0.0000

Figure-5 shows proportion of carbon contents from food plants which are transferred to layers and fixed into parts of layers, faeces and CO_2, CH_4 from digestion and respiration per individual per day. Carbon content at 100 parts in food plants, were fixed in bodies and egg of layers at 62.00%. The rest of carbon contents were released from layers at 38.00%. These carbons created environmental problems.

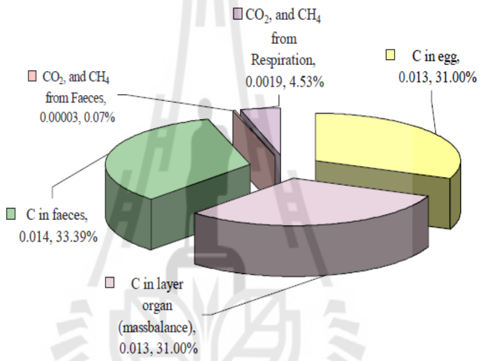

Figure-5. Percentage of C form different parts of layers transferred from plant food per day.

Carbon emission from energy sectors

The survey of farms in studied provinces found that layer farms have used much energy for raising layer per individual per day. Most of energy use including energy for electricity, water pumps, transportation of animals, eggs, feed and animals to slaughterhouses, and LPG or electricity for incubation of baby chicks. Carbon emission from these parts for layer farms was used for feed transportation and small chicks to farms and egg transportation to markets as shown in Table-3.

Figure-5. Percentage of C form different parts of layers transferred from plant food per day.

Carbon emission from energy sectors

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Table-3. Average of C-emission from energy in layer farm (mean ±S.D).

Average c from energy		C-emission (kg.C/ind/day)
Farm	Electricity*	0.002 ± 0.00
	Fuel for transportation**	0.066 ± 0.03
	LPG***	0.002 ± 0.00
Total $C_{emission}$ from energy of farm	kg.C/ind/day	0.07 ± 0.03
	kg.C/wt/day	36.65×10^{-3}

Remark: *CO_2 emission = 0.18 kg.C/kWh,
***CO_2 emission from LPG = 3.0102 kg.CO_2/1kg.LPG, and
**CO_2 emission = 74.5 kg.CO_2/1 Ton/500 km (Keeratiurai and Thanee, 2013)

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Table-3 showed that the carbon emission from using the transportation energy was 94.29%, the carbon emission from using the electricity energy and the carbon emission from using the LPG was 2.86% and 2.86%, respectively. This study showed that the carbon emission from using the transportation energy was quite high in terms of energy using but low in electricity and the using of LPG activities.

Table-4. Ratio of carbon emission from layers and energy use of farms in egg productions.

Ratio of carbon emitted form	Young chicken	layer
Animal (%)	8.46	18.54
Energy use (%)	91.54	81.46

The result of Table-4 shows that the attempt in decreasing carbon emission from the production of the young chickens and layers, the decrease of energy use should be taken into consideration, for instance, the use of gas or LPG instead of the use of chaff or wood. Gas or LPG creates less ash and greenhouse gases than wood and chaff. LPG releases heat energy about 11, 832-12, 034 Kcal/kg equivalent to electricity at 13.70 kWh/kg whilst chaff releases 0.49 kWh, wood (medium density) at 748.23 ± 116.42 kg/m^3; approximately 0.5 cubic meter compare to electricity 0.21 kWh/kg or one kilogram of chaff released energy at 14.27 MJ/kg (3,410.611 Kcal/kg). Base on chemical reaction, propane, combustion (ratio at 70% of gas production) create energy at 499, 000 Kcal/Kmol as shown in Formula 2.

$$C_3H_8+5O_2 \rightarrow 3CO_2+4H_2O+2086 \text{ MJ/Kmol} \qquad (2)$$

The combustion of carbon (in form of wood or chaff) creates energy at 97,000 Kcal/Kmol as shown in Formula 3.

$$C+O_2 \rightarrow CO_2+406 \text{ MJ/Kmol} \qquad (3)$$

It can be advised that the farmers should use LPG instead of wood and chaff in order to create higher heat energy and less environmental problems for egg productions.

Carbon footprint and massflow in egg production

The carbon footprint in egg production is presented in Table-5. The results show that the carbon contents in energy pattern are more important for egg production. The productive carbon footprint of 1 kg of egg was 5.612 kg.CO_2.equivalent. Carbon footprint value of Nakhon Nayok was less than Khon Kaen. It can be concluded that transportation distance of layers; layers feed and layer products in Nakhon Nayok which is shorter than in Khon Kaen are the major factors on carbon footprint values.

Table-5. Carbon footprint of egg production.

Animals	Product	Productive carbon footprint		
		Energy	Faeces and respiration	Total
Layer	kg.CO_2-eq./ 1 kg. living weight / day x 10^{-3}	134.383	3.727	138.110
	kg.CO_2.eq./ 1 kg. egg	5.461	0.151	5.612

The relationship of $C_{emitted}$ and C_{input} (Sig.F<0.05) and C_{fixed} and C_{input} (Sig.F<0.05) at egg duration or average age of 400.63 ± 109.72 days with average value at 0.042 ± 0.004 (kg. C/ind./day) were presented in Figure-6 and also as follow:

$$\text{C-emitted}_{layer} = 0.6283 \ (\text{C-input}_{plant}) - 0.0107 \qquad (4)$$

$$\text{C-fixed}_{layer} = 0.619 \ (\text{C-input}_{plant}) + 0.0003 \qquad (5)$$

Where, C-emitted$_{layer}$ = carbon emitted from layers (kg. C/ind./day)
C-fixed$_{layer}$ = carbon fixation in layers (kg. C/ind./day)
C-input$_{plant}$ = carbon content in animal feed which were transferred to layers by consumption

The example of analysis of the relationship between carbon input to body of layers by consumption (C-input or C_{plant}) and carbon fixation in the term of eggs and in layer (C-fixed) which show positive relation (multiple R=0.95) or relationship at 90.46% (R^2_{adj}=0.90). This can be explained as follows:

H_0: $\beta_1 = 0$ or H_0: C-fixed not depend on C-input by consumption of layers
H_1: $\beta_1 \neq 0$ or H_1: C-fixed depend on C-input by consumption of layers

Hence: $F = \dfrac{MSR}{MSE} = 3785.211 > F_{0.95;\,1,\,398} = 3.84$.

So => Reject hypothesis (Ho)
Significance F = 2.0874 x 10^{-205} which is less than (α = 0.05)

Implication => Carbon which is fixed in eggs and layer bodies correlated linearly with carbon input in layer by consumption at 95% confidence.
To test hypothesis with y axis by
H_0: $\beta_0 = 0$
H_1: $\beta_0 \neq 0$
P-value = 0.477 > 0.05
=> Accept hypothesis

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It can be concluded that the regression equation of C-fixed and C-input of layer is: C-fixed$_{layer}$ = 0.619 (C-input$_{plant}$) + 0.0003

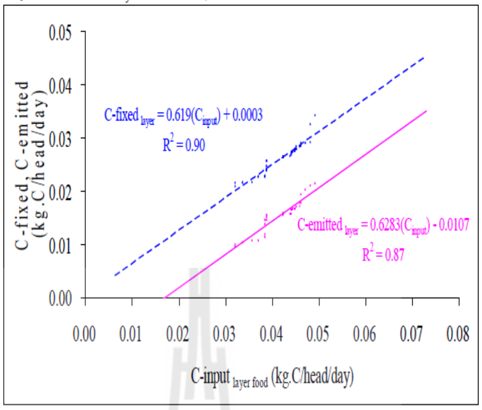

Figure-6. The relationship of $C_{emitted}$ and C_{fixed} to C_{input} at 95% confidence.

Relationship between percentage of carbon and characteristics of feed, egg and faeces, and analysis for environmental problems from animals

Table-6 shows percentage of moisture, volatile solids, ash and carbon content in feed, egg and faeces of layers. Moreover, it shows relationship between percentage of total volatile solids (%TVS) and percentage of carbon (%C) which help in analysis of percentage of carbon in laboratory. The results of this study can analyze environmental problems from egg production.

Table-6. Relationship between moisture, volentile solid and carbon content of food, faeces and egg.

Type	Moisture (%)	TVS (%)	Ash (%)	C (%)	Relationship between % TVS and % C
Animal feed	10.57 ±0.62	68.31±3.15	31.69±3.15	45.58±4.05	% TVS= 0.73(%C)+ 34.92
Egg	40.55±10.62	92.89±2.51	7.11±2.51	50.99 ±1.17	% TVS= 2.01(%C)-9.43
faeces	70.38 ±12.21	57.85±7.41	42.15±7.41	34.09±2.56	% TVS= 2.37(%C)-22.80

Moreover, the result of this study also showed relationship between the rate of egg laying (%) and phase out egg laying (weeks) was y = 19.88Ln(x) + 11.22 at R^2 = 0.45 as shown in Figure-7. Layers would start laying eggs when they were aged 18 or more weeks that it was the first week of phase out of egg laying. They would lay most egg in phase out of egg laying at 11-15 weeks. After 43 weeks, the laying egg would likely decline. Therefore, farmers should not been fed to layers for producing eggs from the 61st weeks of phase out of egg laying or at layers aged 80 weeks. Because of the returns was reduced in egg production. Finally, it wasn't worthwhile to continue. The one layer should been able to lay eggs, throughout the life cycle of feeding, was 308.11 eggs / head at the age of layer was 80 weeks or phase out of egg laying was 61 weeks as shown in the Figure-8. It showed the relation between the accumulation number of eggs per individual and phase out of egg laying was y = 5.4286(x)-27.605 at R^2 = 0.9977.

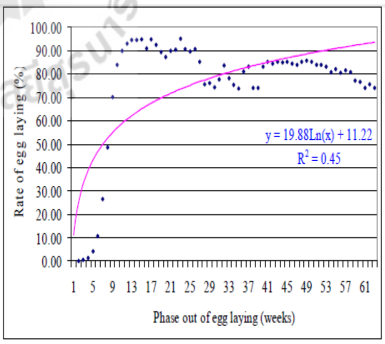

Figure-7. Relation between rate of egg laying (%) and phase out of egg laying (weeks).

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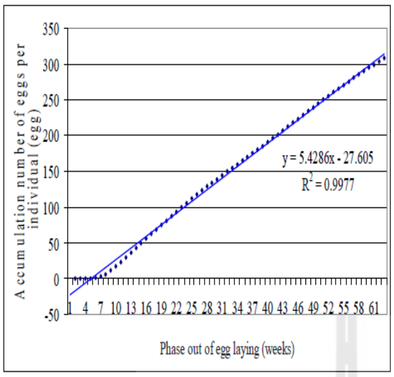

Figure-8. Relation between accumulation number of eggs per individual and phase out of egg laying.

The result of this study also showed that the average egg weight was 62.8±4.45 g./egg and the range of egg weight was 45.0-66.2 g./egg. The weight of the eggs will be very valuable during in phase out of laying eggs from 41 weeks onwards. Figure-9 showed relation between the average egg weight (g.) and phase out of egg laying (weeks) was y = 5.4368Ln(x)+44.935 at R^2 = 0.8388.

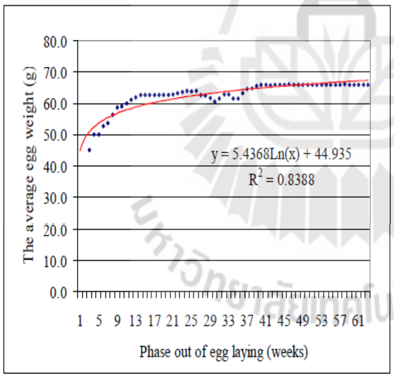

Figure-9. Relation between the average egg weight and phase out of egg laying.

This study surveyed to collect data from farmers who feeding layers in closed house system as evaporation system. It was a system used to control the temperature and the humidity of the house was fixed or variable less. The result showed that the humidity of houses was 74.74 ± 4.04 and temperature in houses was 27.42±0.68 (°C). The layer had the highest percentage of the rate of egg laying in range 84-86% at 27-28 degree Celsius. The relation between the rate of egg laying (%) and temperature (°C) was $y = 1.5605x^4-172.2x^3+7117.6x^2-130611x+897897$ at $R^2 = 0.1631$ as shown in Figure-10.

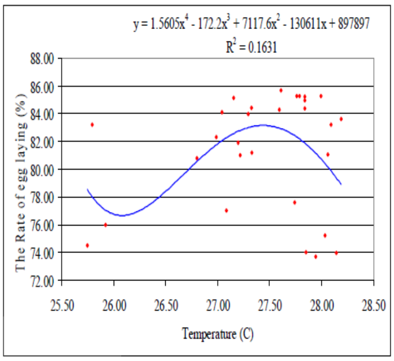

Figure-10. Relation between the rate of egg laying and temperature.

CONCLUSIONS

This case study of egg production was to evaluate carbon emission on layer farms, to investigate the rate of carbon massflow from layer feed to layers and egg in farms and to study the carbon emission in energy patterns from electric energy and petrol used in egg production. The study showed that the carbon emitted per unit from a layer of the young chicken farms and layer farms in Khon Kaen and Nakhon Nayok provinces were 0.004 and 0.006 kg.C/individual/day, respectively and the carbon emission from the using of transportation energy was 94.29%, the carbon emission from the using of electricity energy and the carbon emission from the using of LPG was 2.86% and 2.86%, respectively. The carbon fixation in eggs was 0.013 kg.C/individual/day, and the rate of carbon massflow from layer feed (C_{input}) of Khon Kaen and Nakhon Nayok provinces were 0.027 and 0.042 kg.C/individual/day, respectively. The productive carbon footprint of 1 kg of egg was 5.612 kg.CO_2.equivalent. The ratio of total carbon emitted per unit to total carbon contents per unit in layer feed ($C_{emitted}/C_{input}$) of Khon Kaen and Nakhon Nayok provinces were 14.80 and 14.29, respectively. The ratio of total carbon emitted per day to carbon fixation per day in layers ($C_{emitted}/C_{fixation}$) of Khon Kaen and Nakhon Nayok provinces were 17.39 and 16.67, respectively. The relationship of $C_{emitted}$ and C_{input} (Sig.F<0.05) and C_{fixed} and C_{input} (Sig.F<0.05) at egg duration or average age of 400.63 ± 109.72 days with average value at 0.042 ± 0.004 (kg. C/ind./day) were presented in equations and also as $C\text{-emitted}_{layer} = 0.6283 (C\text{-input}_{plant}) - 0.0107$, and

$C\text{-fixed}_{layer} = 0.619 (C\text{-input}_{plant}) + 0.0003$, respectively. The carbon emission from the using of transportation energy was quite high in terms of energy using but low in the using of electricity and LPG activities. Therefore, farmers should reduce emissions from energy consumption such as reduce electricity utilization in layer farming and reduce distance for layer feed and layers transportation to farms. The using of fuel for transportation should be reduced because it creates the highest carbon emission. The result of this study also

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showed that the average egg weight was 62.8±4.45 g. /egg and 308.11 eggs/head at 80 weeks old of layer. The relation between the average egg weight (g.) and phase out of egg laying (weeks) was the average egg weight in gram = 5.4368Ln(phase out of egg laying in weeks)+44.935 at R^2 = 0.8388. The layer had the highest percentage of the rate of egg laying in range 84-86% at 27-28 degree Celsius. The relation between the rate of egg laying (%) and temperature (°C) was the percentage of rate of egg laying = 1.5605 (temperature in °C)^4-172.2(temperature in °C)^3+7117.6 (temperature in °C)^2-130611 (temperature in °C)+897897 at R^2 = 0.1631.

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ASSESSMENT OF THE CARBON EMITTED FROM THE LAYER AND YOUNG CHICKEN FARMING UNDER THE UNCERTAINTY

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ABSTRACT

Decision making under uncertainty could analyzed environmental problems from the energy using of the tender young chicken and layer farms in egg production. The analysis was based on pay of matrix principle by using all alternatives such as the energy sectors, situations of carbon emission from young chicken farms and layer farms. Then make the decision follow Pay off Matrix, Laplace Rule, Maximax Rules and Minimax Regret Rule on environmental problems. Life cycle inventory is a useful tool for estimating carbon mass of the food support eating. Layers were energy using animals that were raised for their egg, and produced emissions of green house gases such as CO_2 and CH_4. Therefore it was important to study and understand the relationship between the carbon emissions and carbon mass transfer for egg production. This case study of egg production was done to evaluate carbon emission on layer farms, to investigate the rate of carbon massflow from layer feed to layers and egg in farms and to study the carbon emission in energy patterns from electric energy and petrol used of the tender young chicken and layer farms in egg production. The study showed that total carbon emission per individual per year for production of layers was 0.030 tonC./ind./year. According to theories and rules applied in making the decision on environmental problems, they could be concluded that LPG and electricity were the best alternative but transportation energy for layer and egg production caused highest environmental problems among these three alternatives of the energy sectors. The study also showed that in both provinces, Nakhon Nayok and Khon Kaen, immature layers emitted carbon from the use of energy less than mature layers. The carbon emission from the using of transportation energy was quite high in terms of energy using but low in the using of electricity and LPG activities. Therefore, farmers should reduce emissions from energy consumption such as reduce distance for layer feed and layers transportation to farms. The using of fuel for transportation should be reduced because it creates the highest carbon emission.

Keywords: carbon, egg, layer, life cycle inventory, uncertainty.

INTRODUCTION

The food production system as a whole is recognized as one of the major contributors to environmental impacts since it is a great consumer of both energy and natural resources. The current consumption pattern has motivated an increasing interest to report the environmental performance of food products. In this sense, the food production, processing, transport and consumption account for a relevant portion of the environmental greenhouse gas (GHG) emissions. The emissions from food production have increase for two main reasons. First, a growing world population demands more food. Secondly, changes in dietary preferences towards higher-order foods can be increase GHG emissions, with trends towards more intensive of egg production. A growing demand for egg production requires the greater use of the demand for energy. It also induces changes in land use: a process that inevitably leads to CO_2 emissions into the atmosphere. Food production and food consumption are consequently of critical importance in the current and future development of GHG emissions. One of the environmental threats that our planet faces today is the long-term change in Earth's climate and temperature patterns due to global climate change, or the greenhouse effect. CO_2 and CH_4 from human activities are the most important greenhouse gases contributing to global climate change (IPCC, 1995) with CH_4 being 23 times more potent than CO_2 (IPCC, 1996). Chicken and layer are energy-using animals that are raised for their meat and egg, and produce emissions of both CO_2 and CH_4. Carbon is an important element for humans because it is the primary element of both plants and animals and it cycles through living and non-living components. The growth rates of human population drivers the demand of livestock production increase. Livestock animals meet a variety of food needs for people (Thornton *et al*., 2009). They are important nutrient sources of protein in the form of meat and egg (Lauhajinda, 2006). Livestock productions have emitted some greenhouse gases from fertilization, feed production, transportation, energy use in housing, respiration and digestion of livestock (Thanee *et al*., 2009a). The effects of livestock productions due to the utilization and changes of natural resources and environmental factors on the global should be considered (IPCC, 1996). The productive processes should release the least greenhouse gases to avoid such problems and save the Earth. Life cycle inventory (LCI) is an environmental assessment tool for evaluating the impacts that a product has on the environment over the entire period of its life from the raw materials extraction which it was made through the manufacturing, packaging processes, and the use, reuse and maintenance of the product and on to its eventual recycling or disposal as waste at the end of the useful life (Thu Lan and Shabbir, 2008). Layers are energy

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using animals that are raised for their meat and egg, and produce emissions of CO_2. The carbon emission is an alternative for consumers to select the products that release greenhouse gases emission into the environment (Thanee, Dankitikul and Keeratiurai, 2009b). The net carbon production is the rate at which carbon is fixed during growth and laying eggs, and can be used to explain the time averaged C stocks by carbon weight per time (van Noordwijk and Cerri, *et al*., 1997; van Noordwijk and Murdiyarso *et al*., 1998). Therefore, it is important to study the relevant factors concerning the entire production both physical and biotic environment (Thanee and Keeratiurai, 2010). This study deals with the assessment of the carbon emission for egg products which focused on carbon transferred to food chain and fixed in layer meat and eggs. In particular, the estimation of the rate of carbon massflow from animal feed to layer, and including the carbon emissions from electricity, petroleum, and LPG used during egg production were studied in Thailand.

MATERIALS AND METHODS

Study area

Khon Kaen and Nakhon Nayok provinces were selected which represent egg production of Thailand were based on the data of Agricultural Information Center, Office of Agricultural Economics (2004). These provinces have large areas and provide many layer farms and egg productions in these areas as shown in Figure-1 (Department of Livestock Development, 2009).

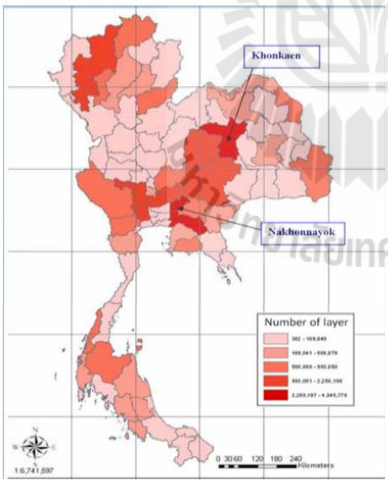

Figure-1. The study of the layer farming area in Khonkaen and Nakhonnayok provinces of Thailand. (From http://www.dld.go.th/index.html, department livestock development, 2009).

LCI methodology applied in this study

Life cycle inventory analysis involves data collection and calculation procedures to quantify the relevant input and outputs of a product system. These inputs and outputs may include the use of resources and releases pollutant to air, water and land associated with the system (Thu Lan, 2007). Life cycle study, data collection represented a time consuming task and it was important to obtain quantitative information concerning various processes in the product system. A significant part of data associated with life cycle of egg production was collected from chick and layer farms. Data for energy consumption, resources and material were obtained directly from farms. A useful instrument facilitating the estimation of gas emissions was the emission factor, which was a representative value attempts to link the associate with the system output. The process of impact assessment analyzes the environmental burdens associated with the material and energy flows determined in the inventory analysis phase though successive steps listed as follow classification, characterization, normalization and weighting (Curran, 1996). The study of life cycle inventory to evaluate the total carbon emission for the egg production in Khonkaen and Nakhonnayok, Thailand was shown in Figure-2.

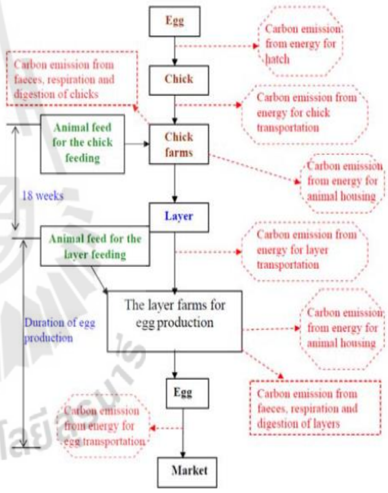

Figure-2. Scope of study on carbon emission from egg production.

Site sampling and analytical methods

The numbers of farms, young chickens, and layers in each district of selected provinces were calculated by determining the numbers of farms young chickens, and layers in the Khonkaen and Nakhonnayok provinces at 95% confidence level (Yamane, 1973; Cavana *et al*., 2001). (According to the population of the study, the totals of population study of the tender young chicken farms*, and layer farms were 2039*, and 1383 respectively.) Therefore, the sample groups were calculated by Taro Yamane's formula (Yamane, 1973) as follows:

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$$n = \frac{N}{1 + Ne^2} \tag{1}$$

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

So, the example of the sample size of young chicken farms for the study has been calculated according to the recommendation as follows:

$n = 2039 / \{1+2039*(0.05)^2\} = 335$ chick farms

With N = 2039, e = 5% (at 95% confidence level), hence the sample size is 335 respondents. The results showed that sample size were 335 young chicken farms, 400 young chickens and 311 layer farms, 400 layers calculated by *Taro Yamane formula*. Animal feed plus their egg and faeces were collected and transferred to the laboratory at Suranaree University of Technology for measurements. Carbon dioxide was measured from living layers at the farms. The evaluation of carbon emission from energy sectors in egg production was calculated with the software of Department of Livestock.

Development as shown in Figure-3 and the analytical methods are as follows:

a) Moisture contents were measured by weighing sample after oven drying at 103-105°C for 24 hours (APHA, AWWA and WEF., 1992).
b) Carbon contents were measured by CNS-2000 Elemental Analyzer (Manlay *et al*., 2004 b, and Keeratiurai and Thanee, 2013).
c) CO_2 was detected by Gas Analyzer (Kawashima, Terada and Shibata, 2000, and Keeratiurai and Thanee, 2013).
d) Volatile solids and ash were analyzed by weighing the known weight of the sample after burning at 550°C for 30 minutes (APHA, AWWA and WEF., 1992).
e) Weight of layer and egg by weighing (Vudhipanee *et al*., 2002, and Keeratiurai and Thanee, 2013).

Figure-3. The software was used to calculate the carbon emission in energy sectors of egg production.

RESULTS AND DISCUSSIONS

Analysis method for the decrease of carbon emission from egg productions and tendency of these egg productions in Thailand

CO_2 emitted from faeces and respiration of a layer was much higher than CH_4 shown in Table-1. This study also showed the ratio of carbon emitted to carbon input, and carbon fixation to carbon input for evolution of the environmental problems (Table-2). The carbon fixation in layer organs and eggs to the sum of carbon contents in layer feed and carbon contents from electric energy, petrol, and LPG used ($C_{fixation}/C_{input}$) was 0.210. The ratio of total carbon emitted per unit to total carbon contents per unit in layer feed and energy used ($C_{emitted}/C_{input}$) was 0.693. The ratio of total carbon emitted per day to carbon fixation per day in organs and eggs of a layer ($C_{emitted}/C_{fixation}$) was 3.308.

Total carbon emission from animal bodies in form of CO_2 and CH_4 from the wet faeces, respiration and digestion of layer as 0.00193 ± 0.00001 kg.C/ind./day including the carbon emission from energy used of farms in Thailand as 0.070 ± 0.03 kg.C/ind./day found that total carbon emission per individual per year for production of layers was 0.030 tonC./ind./year. Base on the Principle of Mass Conservation and the results of this study indicate the total carbon emission of eggs product shown in Formula 2 as follows:

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Total carbon emission from egg production

C-emitted $_{(animal+energy\ use)}$ = (0.03) Layers (2)

Where

C-emitted $_{(animal+energy\ use)}$ = total carbon emission from layers and from energy use for egg production (ton C. / year).
Layers = Number of layers (individual)

Table-1. The average of CH_4 and CO_2 emission from layers on farms.

Animal	Living weight (kg/ head)	Average of gases (kg/head/ day)	CH_4 (kg/ head/ day)	CO_2 (kg/head/day)	Ratio CH_4:CO_2
Layer	1.91 ± 0.15	Faeces	0.000004 ± 0.000000	0.000080 ± 0.000027	0.049
		Respiration	0.000000	0.006954 ± 0.0000	0.000
		Total	0.000004	0.007034	0.00056867
		(CH_4 : CO_2)/living weight			2.977 x 10^{-4}

Table-2. Ratio of C_{input}, $C_{fixation}$, $C_{emitted}$ from feeding in egg production.

Kind of animal	C_{input}	$C_{fixation}$	$C_{emitted}$	The percentage of		
	(kg.C/living weight/day)×10^{-3}			$C_{fixation}$ /C_{input}	$C_{emitted}$ /C_{input}	$C_{emitted}$ /$C_{fixation}$
Layer	21.99	13.61	8.38	20.97	69.35	330.77

Decision making under uncertainty

The results of this study could analyze environmental problems from the energy using of layer and egg production. The analysis was based on pay of matrix principle by using all alternatives such as the energy sectors, carbon emission situation as shown in Table-3. Then make the decision follow theories and laws.

Table-3. The analysis under uncertainty was based on pay of matrix principle.

Alternative of the energy using	Situation of carbon emission from farms (kg.C/head/day)	
	Young chicken farms	Layer farms
Electricity	0.002 ± 0.00	0.002 ± 0.00
Transportation energy	0.044 ± 0.03	0.066 ± 0.03
LPG	0.003 ± 0.00	0.002 ± 0.00

The applied analysis using Laplace Rule to choose the alternative of the energy using which cause the highest environmental problems by setting the probability of the equal situations (n=2), results as in Table-4. According to the Laplace Rule, it could be advised that the best alternative of the energy using in layer and egg production of the transportation energy cause more environmental problems.

Table-4. Result from the application of Laplace rule.

Alternative of the energy using	(C emission from young chicken farms + layer farms)/2
Electricity	0.002 ± 0.00
Transportation energy*	0.055 ± 0.03
LPG	0.003 ± 0.00

Note: *Selected the alternative of the energy using which create maximum environmental problem

The Maximax Rules was applied to indicate the problems of the alternative of the energy using in layer and egg production by selection of situations (Table-3) which got the maximum result and then selected the maximum result from every alternative again. The results were shown in Table-5 which showed that the transportation energy of the layer and egg production was the worst alternative among these three alternatives of the energy sectors.

Table-5. Result from the application of the Maximax rules.

Alternative of the energy using	$\frac{\max\ P_{ij}}{i(x)}$
Electricity	0.002 ± 0.00
Transportation energy*	0.066 ± 0.03
LPG	0.003 ± 0.00

Note: *Selected the alternative of the energy using which created maximum environmental problem

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The Minimax Regret Rule was applied to avoid the regret that the decision was already made in taking the poor alternative. Consideration of the maximum result in each situation was set in the matrix as shown in Table-6. And select the maximum regret in each alternative. Each alternative was selected to find minimum value again. The results were in Table-7 which showed that the electricity and LPG energy for layer and egg production were recommended but transportation energy cause more environmental problems.

Table-6. Regret value of each alternative of the energy sectors.

Alternative of the energy using	Situation of carbon emission from farms (kg.C/head/day)	
	Young chicken farms	Layer farms
Electricity	0.042 ± 0.03	0.064 ± 0.03
Transportation energy	0.000 ± 0.03	0.000 ± 0.03
LPG	0.041 ± 0.03	0.064 ± 0.03

Table-7. Maximum regret value of each alternative of the energy using.

Alternative of the energy using	$\frac{\max Rij}{j}$
Electricity	0.064 ± 0.03
Transportation energy*	0.000 ± 0.03
LPG	0.064 ± 0.03

Note: *Selected the alternative of the energy using which created maximum environmental problem

According to theories and rules applied such as Pay off Matrix, Laplace Rule, Maximax Rules and Minimax Regret Rule in making the decision on environmental problems, it could be concluded that LPG and electricity were the best alternative but transportation energy for layer and egg production caused highest environmental problems among these three alternatives of the energy sectors.

Results of carbon transference and carbon emissions in layer production

The results showed that carbon input of immature layers in Nakhon Nayok province was 0.02 kilogram/individual/day which less than mature layers (C input = 0.042 kg/individual/day). Whereas carbon input in Khon Kaen province for immature layers and mature layers were 0.028 and 0.027 kilogram/individual/day, respectively as shown in Figure-4. Carbon input of both provinces had close values because the farm systems were the same. These values depended upon animal feed which organized by the employers.

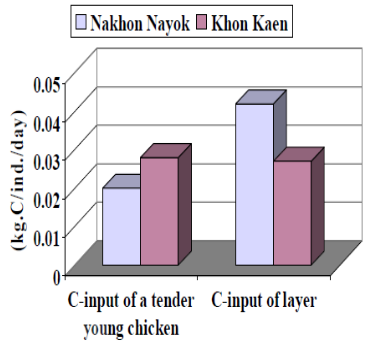

Figure-4. Carbon input of tender young chickens and layers in Nakhon Nayok and Khon Kaen provinces.

Carbon fixation of the both provinces from two types of layers were different which was higher in mature layers than immature layers due to sufficient food for living and egg laying. In Nakhon Nayok carbon fixation of immature layers and mature layers were 0.017 and 0.036 whist in Khon Kaen were 0.019 and 0.023 kilogram/individual/day, respectively. For mature layers, carbon fixation in Khon Kaen was lower than in Nakhon Nayok (0.023 < 0.036) as shown in Figure-5. This probably because of mature layers in Khon Kaen during data collection period were older (post mature layers) than in Nakhon Nayok. Post mature layers fix lower carbon than younger ones.

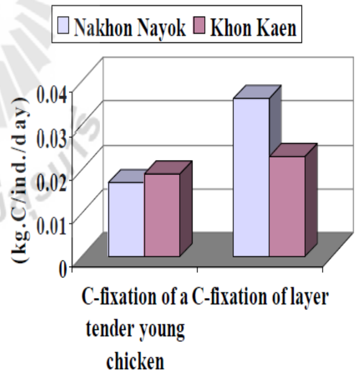

Figure-5. Carbon fixation of tender young chickens and layers in Nakhon Nayok and Khon Kaen provinces.

Carbon emission of both provinces was close value. Immature layers in Nakhon Nayok and Khon Kaen emitted carbon at 0.003 and 0.004 kilogram/individual/day and mature layers at 0.006 and 0.004 kilogram/individual/day, respectively as illustrated in Figure-6. Layer farms in Nakhon Nayok and Khon Kaen have managed farms as the same evap system and the

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same product transportation which were pooled in the centres and then distributed to the markets.

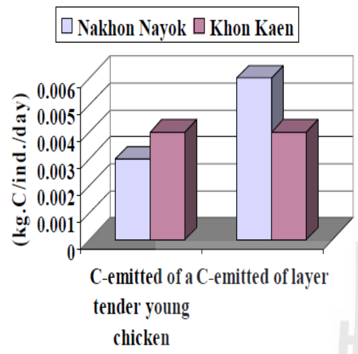

Figure-6. Carbon emitted of tender young chickens and layers in Nakhon Nayok and Khon Kaen provinces.

In both provinces, Nakhon Nayok and Khon Kaen, immature layers emitted carbon from the use of energy less than mature layers. Immature layers in Nakhon Nayok and Khon Kaen emitted carbon from energy use at 0.051 and 0.021 kilogram/individual/day whereas for mature layers at 160.071 and 240.484 kilogram/individual/day, respectively as shown in Figure-7. This duped on rearing durations. The rearing duration for immature layers was 14-16 weeks while for mature layers was 2-3 years. The comparison between these two provinces found that Nakhon Nayok had carbon emission from energy use lower than Khon Kaen. This may be because of transportation distance which Nakhon Nayok transported animal feed from shorter distance (Lopburi province) but Khon Kaen transported feed from longer distance (Nakhon Ratchasima).

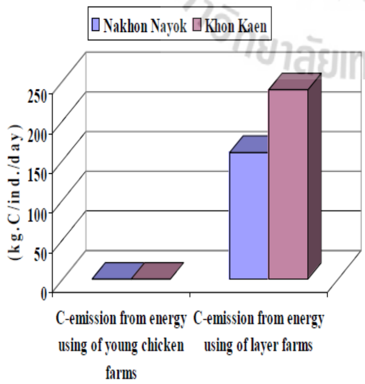

Figure-7. Carbon emission from energy use of layers in Nakhon Nayok and Khon Kaen provinces.

Forecasting trends of carbon emission from egg production

The future trend of carbon emitted from egg production in layer farms was shown in Figure-8. The graph predicts from carbon emitted for egg production to be 0.086 kg.C/head/day or 0.031 ton C/head/year, respectively. These values are based on layers statistics from 2001-2006. The results can be predicted by using the equation from simple linear regression analysis and least square method in net carbon emitted per year by using the following equation; C-emitted of egg production = 6549.5 (year) + 16661, (R^2 = 0.73) where; year is the year figure number from 2001-2011.

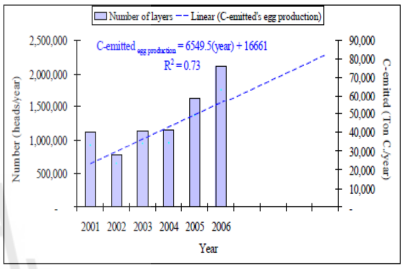

Figure-8. The future trend of carbon contents emitted from egg production.

CONCLUSIONS

The present work is the case study of egg production to evaluate carbon emission on layer farms, to investigate the rate of carbon massflow from layer feed to layers and egg in farms and to study the carbon emission in energy patterns from electric energy and petrol used of the tender young chicken and layer farms in egg production. The study showed that the ratio of total carbon emitted per unit to total carbon contents per unit in layer feed and energy used ($C_{emitted}/C_{input}$) was 0.693. The ratio of total carbon emitted per day to carbon fixation per day in organs and eggs of a layer ($C_{emitted}/C_{fixation}$) was 3.308. Total carbon emission from animal bodies in form of CO_2 and CH_4 from the wet faeces, respiration and digestion of layer as 0.00193 ± 0.00001 kg.C/ind./day including the carbon emission from energy used of farms in Thailand as 0.070 ± 0.03 kg.C/ind./day. Total carbon emission per individual per year for production of layers was 0.030 tonC./ind./year. According to theories and rules applied such as Pay off Matrix, Laplace Rule, Maximax Rules and Minimax Regret Rule in making the decision on environmental problems, they could be concluded that LPG and electricity were the best alternative but transportation energy for layer and egg production caused highest environmental problems among these three alternatives of the energy sectors. The study also showed that in both provinces, Nakhon Nayok and Khon Kaen, immature layers emitted carbon from the use of energy less than mature layers. The carbon emission from the using of transportation energy was quite high in terms of energy using but low in the using of electricity and LPG

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