Journal of Agricultural Technology 2015 Vol. 11(8): 1973-1986
Available online http://www.ijat-aatsea.com
ISSN 1686-9141

Carbon massflow and greenhouse gases emission from pork and goat meat productions in Thailand: case study of Nakhon Ratchasima, Chon Buri and Prachin Buri provinces

Panisara Vichairattanatragul[1], Nathawut Thanee[1*] Prayong Keeratiurai[2]

[1] School of Biology, Institute of Science, Suranaree University of Technology, Nakhon Ratchasima, 30000, Thailand
[2] School of Civil Engineering, Faculty of Engineering, Vongchavalitkul University, Nakhon Ratchasima, 30000, Thailand

Vichairattanatragul P., Thanee N. and Keeratiurai P. (2015). Carbon massflow and greenhouse gases emission from livestock productions in Thailand: case study of Nakhon Ratchasima, Chon Buri and Prachin Buri provinces. Journal of Agricultural Technology 11(8):1973-1986.

One of the environmental threats that our world has faced today is the greenhouse effect. The important greenhouse gases including carbon dioxide (CO_2), nitrogen oxide (NO_x), methane (CH_4) and chlorofluorocarbon (CFC) cause global warming. Livestock production also releases CO_2 and CH_4 to the atmosphere. Swine (monogastric animals) and goats (small ruminant animals) that are raised for their meat and all produce the emissions of both CO_2 and CH_4. Therefore, the purposes of this study were to determine carbon emission factors, to investigate the rate of carbon massflow from animal feed to swine and goats, and to study the carbon emission from energy used in meat production from these farms and slaughterhouses. The research was conducted in 26 districts and 6 sub-communes in Nakhon Ratchasima, 11 districts in Chon Buri and 7 districts in Prachin Buri porvinces during October 2010 to September 2011. Samples of grass and animal feed for feeding in meat production, and the faeces of animals were collected and transferred to the laboratory for analysis. The results revealed that the carbon emitted per living weight from swine and goats were 2.81×10^{-3} and 12.44×10^{-3} kg.C/kg.livestock animal/day, respectively. The rate of carbon massflow from grass and animal feed (C-input) from swine (0.942±0.04 kg.C/swine/day) was lower than from goats (1.130±1.68 kg.C/goat/day). Carbon emission (C-emission) from swine (0.278±0.58 kg.C/swine/day) was lower than from goats (0.443±1.46 kg.C/goat/day). Carbon fixation (C-fixation) in swine and goats were 0.664±0.08 and 0.687±1.06 kg.C/kg.livestock animal/day, respectively. The carbon emitted from pork production was lower than goat meat productions. The result also showed that the performance comparison of C-fixation [(C-input – C-emission) / C-input] of swine and goats were 70.49% and 60.80%, respectively.

Keywords: Carbon emission, Carbon massflow, Carbon footprint, Swine and goat productions

Introduction

The food production system as a whole is recognized as one of the major

***Coressponding Author:** Nathawut Thanee **E-mail:** nathawut@sut.ac.th

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 (FAO, 2013). In this sense, the food production, processing, transport and consumption account for a relevant portion of the environmental greenhouse gases (GHG) emissions (Keeratiurai *et al*., 2013; Keeratiurai and Thanee, 2013). One of the environmental threats that our planet faces today is the long-term change in Earth's climate and temperature patterns due to the global climate change and greenhouse effect. Carbon dioxide ($CO_{2)}$ and methane (CH_4) from human activities and meat production are the most important greenhouse gases contributing to global climate change (IPCC, 1995; FAO, 2006). Methane being 23 times more potent than CO_2 (IPCC, 1996). Livestock productions have emitted greenhouse gases from fertilization, feed production, transportation, energy use in residence, respiration and digestion of livestock (Thanee *et al*., 2009a). The effects of livestock productions due to the employment and changes of natural resources and environmental factors on the global should be considered (IPCC, 2001; FAO, 2006). The productive processes should release the least greenhouse gases to avoid such problems and save the Earth. The carbon footprint is a measure of the exclusive total amount of CO_2 emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product (Thu, 2007; Thu and Shabbir, 2008). Swine and goats have been raised for their meat, and have emitted the GHG. The carbon footprint is an alternative for consumers to select the products that release the least greenhouse gases into the environment (Thanee *et al*., 2009b). Therefore, it is important to study the relevant factors concerning the entire production both physical and biotic environments (Thanee and Keeratiurai, 2010). Moreover, if Thailand needs to be the leadership in trade of livestock production exports of the ASEAN Economic Community (AEC), the country has to investigate the basic data of carbon massflow of the livestock production and develop the process to achieve the least environmental impact.

The objectives of this study were to assess carbon transference and carbon emission, and to compare the environmental impact in pork and goat meat productions in Thailand.

Materials and methods

Study area

Nakhon Ratchasima, Chon Buri and Prachin Buri provinces were selected as study areas based on the data of Agricultural Information Center, Office of

Agricultural Economics (2004). These provinces have provided many swine and goats farms and have supplied live animals and meat to other areas of Thailand (Department of Livestock Development, 2013).

Site sampling and analytical methods

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

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

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

The calculation showed that sample sizes were 400 swine farms, 400 swine and 332 goat farms, 400 goats. Animal feed, 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 and goats at the farms. Parameters for the evaluation of carbon transference and emission were moisture contents (APHA *et al*., 1992), carbon contents by CHN-628 Elemental Analyzer (Manlay *et al*., 2004 a; Manlay *et al*., 2004 b; Keeratiurai and Thanee, 2013), CO_2 by Gas Analyzer (Kawashima *et al*., Terada and Shibata 2000; Keeratiurai and Thanee, 2013), Volatile solids (APHA *et al*., 1992) and Weight of swine and goats by weighing (Vudhipanee *et al*., 2002; Keeratiurai *et al*., 2013). Results of these parameters were also used to compare the environmental impacts from swine and goat meat productions.

Results and discussions

Carbon input and carbon emission

The carbon contents in the unit of kilogram carbon per kilogramme of livestock animal production per day (kg.C/kg.livestock animal/day) were used to study carbon massflow from animal feed to biomass of different livestock animals (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 in swine and goats in the Nakhon Ratchasima, Chon Buri and Prachin Buri provinces were 0.942±0.04 kg.C/swine/day and 1.130±1.68 kg.C/goat/day. Carbon fixation was calculated by using 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 and goats were 0.664±0.63 kg.C/swine/day and 0.687±1.06 kg.C/goat/day, respectively. The carbon emission (C-emission) from faeces, enteric fermentation, and respiration were 0.278±0.58 kg.C/swine/day and 0.443±1.46 kg.C/goat/day. There was no significantly statistical difference ($P \leq 0.05$). The swine had higher carbon fixation efficiency (70.49%) than goats (60.80 %). Nevertheless, the goats had higher carbon emission from the same animal weight than swine at 12.440×10^{-3} kg.C/goat/day and 2.809×10^{-3} kg.C/swine/day which the values were significantly statistical different ($P \leq 0.05$). These results are shown in Tables (1 and 2).

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

Content	Swine	Goats
C-input (kg.C/ind./day)	0.942±0.04	1.130±1.68
C-fixation (kg.C/ind/day)	0.664±0.08	0.687±1.06
C-emission (kg.C/ind/day)	0.278±0.58	0.443±1.46
C-emission /C-input (%)	29.51	39.20
C-emission /C-fixation (%)	41.87	64.48
Fixation efficiency C = (C-input – C-emission)/C-input (%)	70.49	60.80

Table 2 Carbon emission per individual per day and carbon emission per day at same weight of animals (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 from same weight (kg.C/kg.ind.wt/day) x 10^{-3}
Swine	1.31 ± 0.41	1.32	0.278 ± 0.58	98.94 ± 2.47	2.809
Goat	1.26 ± 2.37	3.54	0.443 ± 1.46	35.61 ± 1.63	12.440

Each kind of livestock animal emitted different total carbon per kilogramme which a goat emitted higher carbon per day (0.443±1.46 kg.C/goat/day) than a swine 0.278±0.58 kg.C/swine/day). The carbon content in the form of dry faeces of goat (56.21%) was lower than in swine (61.14%) but carbon in form of carbon dioxide (CO_2) and methane (CH_4) from respiration and excretion of goat (43.51%) was higher than of swine (38.14%) as shown in (Fig. 1).

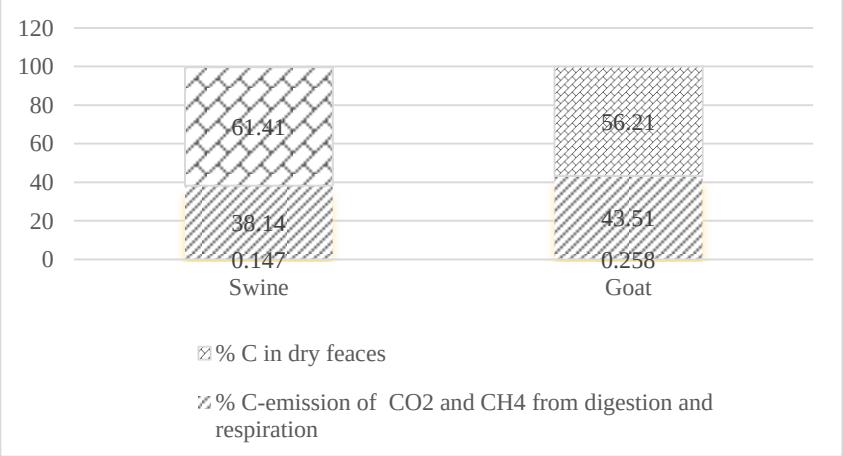

Fig. 1 Ratio of carbon emission per individual per day from different Animals

The average amount of carbon which was released in the form of CO_2 and CH_4 from faeces, digestion and respiration of each animal is shown in (Table 3). Goat emitted higher proportion of CO_2 and CH_4 at 354.279 x 10^{-4} time compared with the same weight of livestock animals. The global warming potentials (GWP) of CH_4 is estimated to be 21 times of CO_2 and nitrous oxide (N_2O) almost 310 times of CO_2 (IPCC, 2001). Therefore, this study can be concluded that a goat had more contribution to the cause of global warming than swine.

Table 3 Gases from swine and goats in farms of Thailand (Mean ± S.D)

Animal	Mean of gas from	CH_4 (kg./ind/day)	CO_2 (kg./ind/day)	Ratio CO_2	CH_4 : CO_2	CH_4 : CO_2 At same weight (1 kg. ani)
Swine	Faeces	0.0099 ± 0.00000	0.0066 ± 0.00030	1.500	Total 2 sources = 0.034	3.413 x $^{4-}$10
	Digestion and respiration	0.0468 ± 0.00440	1.6727 ± 0.12860	0.028		
Goat	Faeces	0.0005 ± 0.00002	0.0005 ± 0.00016	0.400	Total 2 sources = 1.262	354.279 x 10^{-4}
	Digestion and respiration	1.1182 ± 0.00630	0.8860 ± 0.00021	1.262		

The comparison of the percent of average carbons which were fixed in this two animals per average carbon content in animal feed for each livestock animal per day)C-fixation/C-input) found that swine fixed higher (70.49%) carbon from animal feed than goats (60.80%) as shown in (Table 4).

Table 4 Average percentage of carbon fixation in animal parts (mean ± S.D.)

Animal	Total meat (%)	Total entrail (%)	Skin, blood, bone, head, ect.	C-fixation / C-input
Swine	40.23±2.83	7.89±0.81	52.97%	70.49%
Goat	43.66±1.64	9.27±0.93	48.67%	60.80%

The rest of carbon contents were released from swine and goats through the excretion of waste (29.51%), and respiration and digestion (39.20%). These carbons are an important part in causing the environmental problems. The result showed that swine fixed higher carbon in their bodies and released lower carbon compare to goats. In addition, the swine had higher carbon fixation efficiency (68.79%) than goats (63.09%). The results are illustrated in (Fig. 2 and 3).

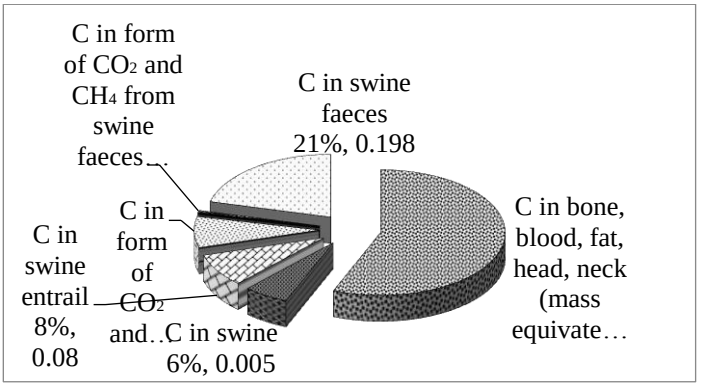

Fig. 2 Percentage of C form different parts of swine transferred from animal feed per day

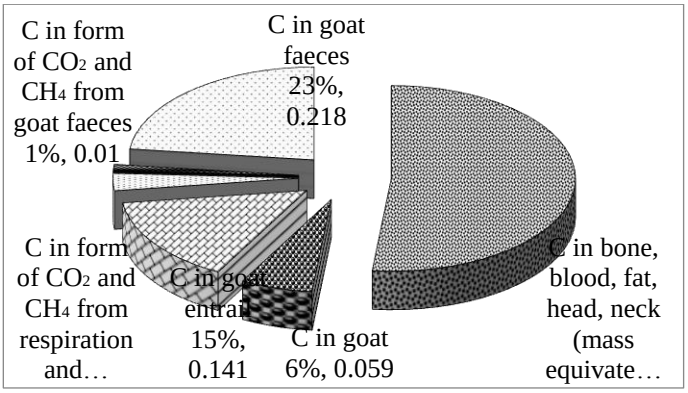

Fig. 3 Percentage of C form different parts of goats transferred from animal feed per day

Carbon emission from energy use in pork and goat meat productions

The survey of farms and slaughterhouses in Nakhon Ratchasima, Chon Buri and Prachin Buri provinces found that swine and goat farms used much energy for raising livestock animal per day (kg.C/kg.livestock animal). Most of energy use including energy for water pumps, transportation of animals, animal feed and animals to slaughterhouses, and electricity for incubation of small animals. The results showed that at the same weight of animal productions goats emitted higher carbon (82.34×10^{-3} kg.C/ kg.goat/day) than swine (8.39×10^{-3} kg.C/ kg.swine/day) as shown in (Table 5).

Table 5 Average of C-emission from energy in farm and slaughterhouse (mean ±S.D)

Average C from energy		C-emission (kg.C/kg.livestock/day) swine	goats
Farm	Electricity	0.02 ± 0.02	0.002 ± 0.00
	Fuel for transportation	0.81 ± 0.85	2.930 ± 0.03
	Fuel for machine or LPG	N.D.	N.D.
	Total C from energy/ kg.livestock /day	0.83	2.93
	Total for energy/1 kg.livestock /day	8.39×10^{-3}	82.34×10^{-3}
Slaughterhouse	Electricity	0.05 ± 0.04	0.009 ± 0.0040
	Fuel for transportation	0.03 ± 0.00	0.037 ± 0.0016
	Wood chaff LPG	2.28 ± 1.02	0.320± 0.0010
	Total C from energy kg.livestock /day	2.36	0.37
	Total for energy/1 kg.livestock/day	23.85×10^{-3}	10.39×10^{-3}
Total C-emission from energy of two sources	kg.C/ kg.livestock /day	3.19	3.30
	kg.C/ 1 kg.livestock /day	32.24×10^{-3}	92.67×10^{-3}

The comparison of farms and slaughterhouses found that most of carbon emission from goats was used for transportation of feed and animal to markets while from swine were used in slaughterhouses. This energy was from chaff and wood as shown in (Fig. 4). Carbon emissions from swine and goats production from energy used were 3.19 and 3.30 kg.C/kg.livestock./day, respectively.

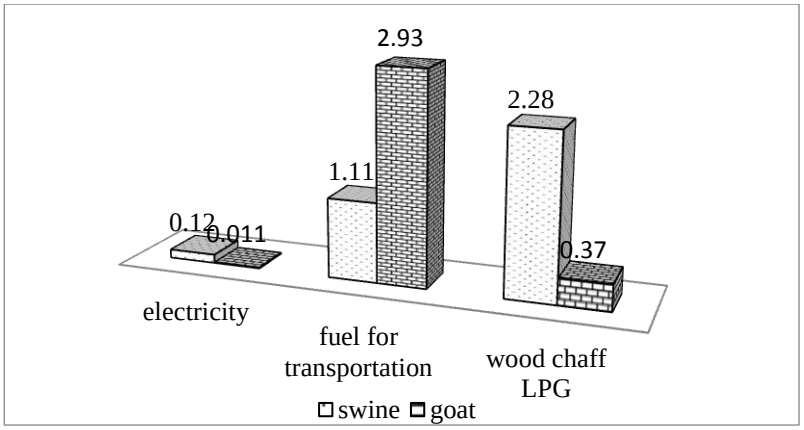

Fig.4 Total carbon emission from the use of electricity, fuel, LPG for production of pork and goats meat production

At the same weight of each animal found that swine and goats emitted carbon from energy use for meat productions at 49% and 51 %, respectively as illustrated in (Fig. 5). Total carbon emission from goat production was higher than swine at 92.67 x 10^{-3} and 32.24 x 10^{-3}kg.C/average animal weight/day, respectively.

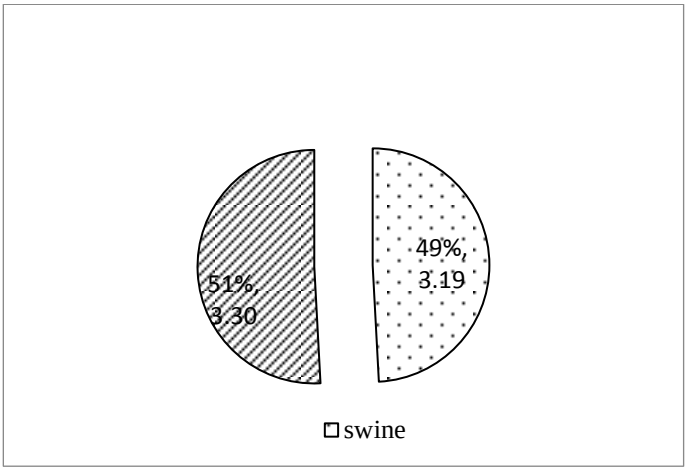

Fig. 5 Ratio of carbon emission from energy for pork and goat meat production of farms and slaughterhouses at same animal weight

Analysis for environmental problems from swine and goat productions

The results of average dry weight of animal feed, meat and faeces which were investigated 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 goats released higher faeces (31.96%) than swine (26.17%) as shown in (Table 6). Moreover, swine consumed only 1.94% of dry weight animal feed and released only 0.51% of dry weight faeces which was positively correlated with relationship between C-input and C-emision $_{\text{livestock animal.}}$

Table 6 Average and relationship between carbon, dry weight of animal feed and faeces from each animal per day weight of each animal (mean ± S.D.)

Animal	Average rearing wt		Dry faeces (kg/ind/day)	Dry food plant for animal consumption (kg/ind/day)		CH_4 wt from animal per dry food plant wt (%)	Dry food wt consumption per live animal wt (%)	Dry faeces wt per live animal wt (%)	Dry faeces wt per dry food plant wt (%)	C in form of $CO_2 + CH_4$ per food plant (%)	C faeces per C food plant (%)
Swine	131.24 22.64	±	0.51	1.96 0.68	±	0.36	1.94	0.51	26.17	8.58	20.25
Goats	152.64 4.68	±	1.16	0.85 0.02	±	0.41	2.42	3.26	31.69	12.28	24.88

Consequenly, the results of this study can be used to analyze the 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 7) then make the decision follow the methods of Sullivan *et al.*, 2003.

Table 7 The carbon emission from situation of swine and goat productions

Alternative of livestock	Suituation of carbon emission (kg.C/wt/day)	
	C-emission from animal	C-emission from energy use
Swine	2.81×10^{-3}	32.24×10^{-3}
Goats	12.44×10^{-3}	92.67×10^{-3}

The Laplace's Rule was applied to choose the kind of livestock which caused the highest environmental impact by setting the probability of the equal scenarios (n=2) as shown in (Table 8). According to the Laplace's Rule, results of this analysis could be concluded that swine was the best alternative while goats created the highest environmental impacts between these two livestock productions.

Table 8 Result from the application of Laplace's Rule

Alternative of livestock	(C-emission from animal + C-emission from energy use)/n
Swine	(2.81+32.24)/2 = 18.93
Goats*	(12.44+92.67)/2 = 58.78

Remark: *Selected livestock create maximum environmental problem

According to theories and rules applied which were mentioned above in making the decision on environmental impacts, it can be concluded that pork production is better alternative than goat production. In the other hand, the goat meat production causes the highest environmental impacts.

Conclusions

The carbon massflow of swine and goat productions are shown in (Fig. 6 and 7). According to theories and rules applied such as Pay off Matrix and Laplace's Rule in making the decision on environmental problems, the studies could be concluded that pork production was better alternative than goat meat production. On the other hand, goat meat production caused higher environmental problems.

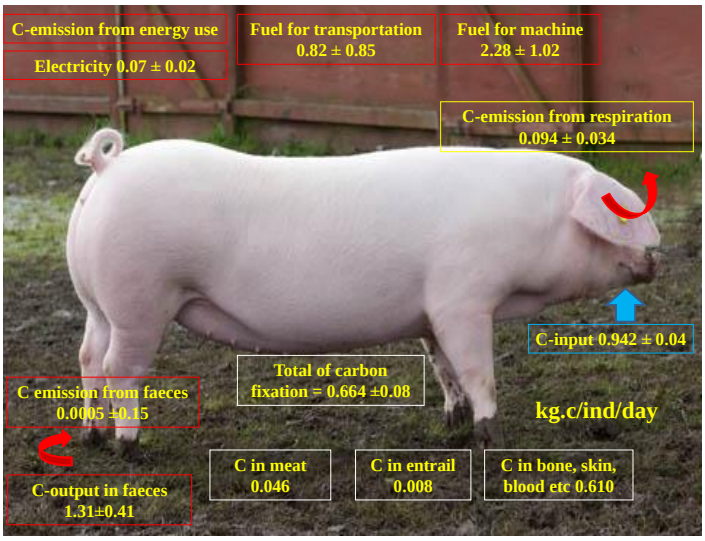

Fig. 6 Diagram of carbon input, carbon fixation and carbon emission from swine production

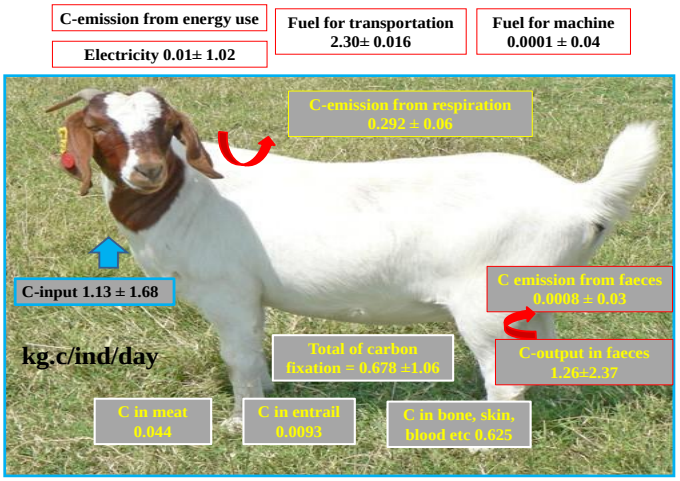

Fig. 7 Diagram of carbon input, carbon fixation and carbon emission from goat production

Acknowledgement

The researchers acknowledge the Centre for Scientific and Technological Equipment, Suranaree University of Technology for providing laboratory analyses. This work received financial support from National Research Council of Thailand, fiscal year 2010-2011.

References

APHA, AWWA, WEF. (1992). Standard Methods for the Examinations of Water and Wastewater. 20th Ed. American Public Health Association, Wash. D.C., USA. p. 445.

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

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

Department of Livestock Development. (2013). Livestock Statistics Data. [On-line]. Available: http://www.dld.go.th/index.html. Accessed date: December 2013.

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

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

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

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

Intergovernmental Panel on Climate Change (IPCC). (1996). IPCC Guidelines for National Greenhouse Gas Inventory. [Online]. Available: http://www.ipccnggip.iges.or.jp/public/gl/invs1.htm. Accessed date: March 2008.

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

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

Keeratiurai P. and Thanee N. (2013). Comparison of Carbon Equivalent Emissions under Uncertainty of Energy Using for Industries of Pig and Broiler Meat Production. ScienceSeries Data Report 5(5): 55-65.

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

Klarenbeek JV, Pain BF. (1998). Anglo-Dutch experiments on odor and ammonia emissions from landspreading livestock wastes. IMAG Research Report 88-2, Wageningen, Netherlands.

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

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

National Transportation Statistics. (2000). C-emission from petrol used for transporting. [On-line], Available: http://www.vcacarfueldata.org.uk/downloads, http://www.gdrc.org/uem/CO2-Cal/CO2-Calculator.html. Accessed date: March 2007.

Pollution Control Department. (2003). Acid Deposition Control Strategy in the Kingdom of Thailand. Japan International Cooperation Agency. Rebitzer G., et al. 2004. Review Life cycle assessment. Part 1: Framework, goal, and scope definition, inventory analysis, and application. Environmental International Academic Publishers. pp. 701-720.

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

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

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

Thanee N. and Keeratiurai P. (2010). Carbon massflow and greenhouse gases emissions from egg production using life cycle assessment in Nakhon Ratchasima province, Thailand. Proceedings of the 5th GMSARN International Conference 2010 on "Sustainable

Development and Climate Change: Challenges and Opportunity in GMS" 17-19 November 2010, Luang Prabang City, Lao PDR. pp. 1-5.
Thu LTN. (2007). Life cycle assessment of bio-ethanol as an alternative transportation fuel in Thailand.
Thu LTN. and Shabbir HG. (2008). Life Cycle Assessment of Fuel Ethanol from Cassava in Thailand. Spinger-Verlag Academic Publishers 147-154.
TGO. (2011). Common data of carbon footprint analyzes. [on-line]. Available: http://conference.tgo.or.th/download/tgo_or_th/publication/CFP_Guideline_TH_Edition 3.pdf.
UNECE. (2004). Task Force on Emission Inventories and Projections. [On-line]. Available: http://tfeip-secretariat.org/unece.htm.
Van Noordwijk M., Cerri C., Woomer PL., Nugroho K. and Bernoux M. (1997). Soil carbon dynamics in the humid tropical forest zone. Geoderma 79: 187-225.
Van Noordwijk M., Murdiyarso D., Hairiah K., Wasrin U.R., Rachman A. and Tomich TP. (1998). Forest soil under alternatives to slash and burn agriculture in Sumatra,
Indonesia, pp. 175-185. In: A. Schulte and D. Ruhiyat, (Eds.). Soils of Tropical Forest Ecosystems: Characteristics, Ecology and Management, Springer- Veriag, Berlin, Germany.
Vudhipanee P., Lortae K. and Imvatana S. (2002). Comparative efficiency of weight prediction equations of swamp buffalo. Animal Husbandry Division. : DLD. Available: www.dld.go.th/research-AHD/Webpage/2545/45 (3)-0406-147.pdf. Accessed date: June 2007.
Yamane T. (1973). Mathematics for Economists: An Elementary Survey. 2nd Ed. Prentice-Hall, New Delhi, India. p.714.