COMPARISON OF CARBON EMITTED FROM OX, BUFFALO, PIG, AND CHICKEN FARMS AND SLAUGHTERHOUSES IN MEAT PRODUCTION

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Received: Feb 20, 2009; Revised: Apr 21, 2009; Accepted: Apr 23, 2009

Abstract

The carbon budget of oxen, buffaloes, pigs, and chickens during meat production were studied to determine carbon emitted from farms, to investigate the rate of carbon massflow from plants to ox, buffalo, pig, and chicken in the food chain and to study the carbon emission in energy patterns that was used in meat production in Nakhon Ratchasima province. The study showed that the carbon emitted per unit from farms and slaughterhouses in ox, buffalo, pig, and chicken meat production was 0.0066, 0.0051, 0.0339, and 0.0851 kg.C/kg. living weight/day, respectively. The carbon fixation in meat and organs of ox, buffalo, pig, and chicken was 0.0102, 0.0104, 0.0062, and 0.0111 kg.C/kg. living weight/day, respectively, and the rate of carbon massflow from grass and animal feed was 0.0148, 0.0143, 0.0087, and 0.0184 kg.C/kg. living weight/day, respectively. This study also showed that the percentage of carbon fixation in meat and organs of ox, buffalo, pig, and chicken to the sum of carbon contents in grass and feed used for feeding was 69.24%, 72.53%, 71.18%, and 60.45%, respectively. The ratio of total carbon emitted to total carbon contents in grass and feed used for ox, buffalo, pig, and chicken feeding was 0.31, 0.28, 0.28, and 0.39, respectively. The ratio of total carbon emitted per day to carbon fixation per day in meat and organs of ox, buffalo, pig, and chicken was 0.45, 0.38, 0.40, and 0.65, respectively. Ox production produced more environmentally harmful carbon than buffalo production. The results also showed that the ratio of CH_4 to CO_2 emitted from faeces, enteric fermentation and respiration of ox was higher than the value from buffalo. For the equal quantity of meat production, it is suggested that ox meat production should be reduced while the buffalo meat production should be increased to lessen the environmental impact. Moreover, of the four animals, carbon emitted from buffalo and pig will give less environmental problems and farming/slaughterhouses should be more encouraged than ox and chicken farming/slaughterhouses. The carbon contents emitted in meat production in ton C per year from ox, buffalo, pig, and chicken farms and slaughterhouses in Nakhon Ratchasima province can be shown by using the equation from mass conservation and the numbers of animals as follows; $C_{emitted}$ = (0.73) Oxen + (0.85) Buffaloes + (1.25) Pigs + (0.07) Chickens.

Keywords: 2024-T351 aluminium alloy, crack coalescence, fatigue, friction stir welding

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Introduction

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, 2001). Ox and buffalo are herbivores while pig and chicken are energy-using animals that are raised for their meat, 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 cycles through living and non-living components (Lauhajinda, 2006). One product of carbon fixation is the protein in meat and animal products. The focus of this study is on carbon which is transferred to the food chain and fixed in meat. The net carbon production is the rate at which carbon is fixed during growth, and can be used to explain the time averaged C stocks by carbon weight per time (van Noordwijk *et al*., 1997, 1998). Therefore, it is important to study and understand the relationship between the carbon emissions, carbon massflow, and energy used for meat production.

The primary objective of this study was to determine carbon emitted factors for ox, buffalo, pig, and chicken farms. To accomplish this, we studied the rate of carbon massflow from plants to an ox, a buffalo, a pig, and a chicken, and included the carbon emissions from electricity, LPG, wood or paddy husk, and petroleum used during meat production in Nakhon Ratchasima.

Materials and Methods

Study Area

Ox, buffalo, pig, and chicken farms and slaughterhouses were studied in 26 districts and 6 subdistricts of Nakhon Ratchasima province which are shown in Figures 1 and 2, respectively. Nakhon Ratchasima province has an agricultural area of 12,469 square kilometers and is the largest area of ox farms in Thailand (Center for Agricultural Information, Office of Agricultural Economics, 2004).

Size of Samples and Sampling Methods

The numbers of farms, and numbers of oxen, buffaloes, pigs, and chickens, in each district and subdistrict were calculated by determining the numbers of ox, buffalo, pig, and chicken farms and the numbers of oxen, buffaloes, pigs, and chickens in the province (Yamane, 1973; Cavana *et al*., 2001). The results showed that these were 398 ox farms, 390 buffalo farms, 390 pig farms, and 340 chicken farms, 17 ox and buffalo slaughterhouses, 7 pig slaughterhouses, and 18 chicken slaughterhouses, totalling 400 oxen, 398 buffaloes, 400 pigs, and 400 chickens from farms. Grass and feed, plus their meat and faeces were collected and transferred to the laboratory at Suranaree University of Technology for measurements. Results from analytical methods are as shown in Table 1.

Previous Researches and Calculating Methodology for $C_{emitted}$, $C_{fixation}$, and C_{input}

According to Thanee *et al*. (2008), ox production produced more environmentally harmful scarbon than buffalo production. For the equal quantity of meat production, it is suggested that decreasing ox meat productison and increasing buffalo meat production can decrease the environmental problems. The ratio of CH_4 to CO_2 emitted from faeces, enteric fermentatiosn and respiration of ox was greater than the value for buffalo (Dankittikul and Keeratiurai, 2008). Carbon was calculated by a mass balance method. C_{input} was the carbon contents transferred from plant and animal feed to animals by feeding (kg.C/head/day). $C_{emitted}$ was the carbon contents emitted from animal faeces (C_{output}), enteric fermentation and respiration ($C_{emission}$). Thus, C_{output} plus $C_{emission}$ make for $C_{emitted}$ (kg.C/head/day). The Cinput minus the carbon contents emitted from animal faeces, enteric fermentation, and respiration ($C_{emitted}$) was the carbon mass fixed in the body ($C_{fixation}$). Whereas the $C_{fixation}$ (kg.C/head/day) was the carbon contents fixed in meat and organs of animals (Thanee *et al*., 2008).

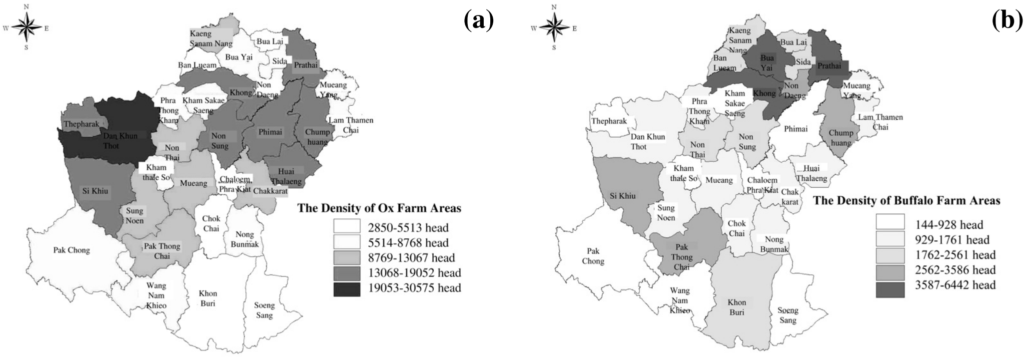


Figure 1. Ox and buffalo farm areas in Nakhon Ratchasima province (Department of Livestock Development, 2005)
(a) Ox farm areas
(b) Buffalo farm areas

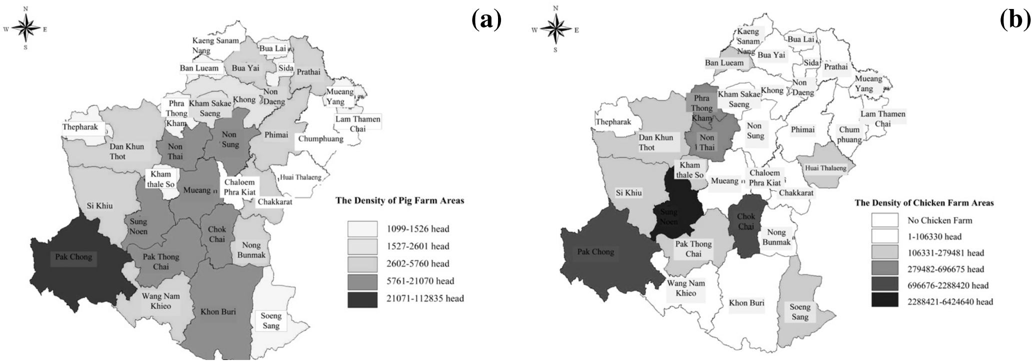


Figure 2. Pig and chicken farm areas in Nakhon Ratchasima province (Department of Livestock Development, 2005)
(a) Pig farm areas
(b) Chicken farm areas

Table 1. Methods for property analysis of animal feed, meat, entrails, gases, and faeces from animals

Properties	Analytical methods
Moisture content	By weighing sample after oven drying at 103-105°C for 24 h (Manlay *et al*., 2004).
Carbon content	By CNS-2000 ELEMENTAL ANALYZER (Manlay *et al*., 2004) and GAS ANALYZER (Kawashima *et al*., 2000).
Volatile solids and ash	By weighing the known weight of the sample after burning at 550°C for 30 min (APHA, AWWA, WEF., 1998).
Weight	By weighing or using cattle weighing tape (Vudhipanee *et al*., 2002).

Results and Discussion

The Rate of Carbon Contents Massflow and the Carbon Emitted

The rate of carbon massflow from animal feed for feeding to the biomass of ox, buffalo, pig, and chicken (C_{input}) was determined and found to be 4.46 ± 1.93, 6.51 ± 3.14, 0.879 ± 0.30, and 0.043 (0.007 kg.C/head/day, respectively are shown in Table 2.

Table 2 also shows that the carbon fixation of ox, buffalo, pig, and chicken was 3.09 ± 1.97, 4.72 ± 3.14, 0.626 ± 0.256, and 0.026 ± 0.007 kg.C/head/day, respectively. The carbon emitted for ox, buffalo, pig, and chicken was 1.38 ± 0.36, 1.80 ± 0.51, 0.253 ± 0.058, and 0.017 ± 0.006 kg.C/head/day, respsectively. CO_2 and CH_4 gases which were emitted from faeces, enteric fermentation and respiration of animals are shown in Table 3. Figures 3 and 4 show the ratio of the carbon massflow by feeding. The carbon mass fixed in the biomass of ox, buffalo, pig, and chicken

Table 2. The average of C_{input}, $C_{fixation}$, $C_{emitted}$, C_{output}, and $C_{emission}$ of CO_2 and CH_4 from animals on farms (average ± standard deviation)

Kind of animal			Ox	Buffalo	Pig	Chicken
C_{input} massflow from plant by feeding (kg.C/head/day)			4.46 ± 1.93	6.51 ± 3.14	0.879 ± 0.30	0.043 ± 0.007
C_{input} (kg.C/kg. living weight/day) x 10^{-3}			14.76	14.27	8.71	18.38
$C_{fixation}$ (massbalance) (kg.C/head/day)	Meat		0.031	0.0198	0.047	0.0046
	Entrails		0.004	0.0039	0.007	0.0008
	Bone, skin, blood, etc.		3.055	4.696	0.572	0.021
	Total $C_{fixation}$		3.09 ± 1.97	4.72 ± 3.14	0.626 ± 0.256	0.026 ± 0.007
$C_{fixation}$ (kg.C/kg. living weight/day) x 10^{-3}			10.22	10.35	6.20	11.11
$C_{emitted}$* (kg.C/head/day)	Dried faeces (C_{output})		0.894 ± 0.31	1.12 ± 0.44	0.178 ± 0.044	0.015 ± 0.006
	$C_{emission}$ of CO_2 and CH_4 gases	Faece	0.011 ± 0.005	0.021 ± 0.012	0.0004 ± 0.0001	0.00004 ± 0.00004
		Enteric fermentation and respiration	0.471 ± 0.188	0.66 ± 0.277	0.075 ± 0.037	0.0018 ± 0.0000
	Total $C_{emitted}$		1.38 ± 0.36	1.80 ± 0.51	0.253 ± 0.058	0.017 ± 0.00
$C_{emitted}$ (kg.C/kg. living weight/day) x 10^{-3}			4.57	3.95	2.48	7.27
Living weight (kg./head)			302.25 ± 100.72	456.10 ± 134.38	100.91 ± 6.31	2.34 ± 0.34

*$C_{emitted} = C_{output} + C_{emission}$

was 69.18%, 72.38%, 71.14%, and 60.70%, respectively and that emitted from faeces, enteric fermentation and respiration was 30.82%, 27.62%, 28.86%, and 39.30%, respectively. Carbon emitted which contributes to environmental problems show that buffalo and pig encourage less global climate change than ox and chicken because buffalo and pig fixed the carbon contents in their bodies more efficiently than ox and chicken.

Carbon Contents Emission from Energy Sectors for Meat Production

The pig and chicken farms in Nakhon Ratchasima province used more energy in kg. C/kg. living weight/day than ox and buffalo farms for feeding. The first sector was electric light and heat energy. The second sector was petrol used for animal transport. The third sector was petroleum for cutting grass and transferring it to farms for feeding. The fourth sector was liquefied petroleum gas (LPG) used for heating. The $C_{emission}$ per unit of all 3 energy sectors at ox, buffalo, and chicken farms were 0.09, 0.08, and 0.049 kg.C/head/day, respectively. The $C_{emission}$ per unit of all 2 energy sectors at pig farms were 0.83 kg.C/head/day, respectively. The slaughterhouses in Nakhon Ratchasima used energy for electric light, boiling the water for animal skin cleaning, and delivering meat from slaughterhouses to markets with $C_{emission}$ per unit of energy used for ox, buffalo, pig, and chicken meat production being 0.52, 0.44, 2.34, and 0.1332 kg.C/head/day, respectively. On the other hand, the $C_{emission}$ of energy used for meat production by farms and slaughterhouses was 2.05×10^{-3}, 1.14×10^{-3}, 31.41×10^{-3}, and 77.86×10^{-3} kg.C/kg. living weight/day, respectively. The average of $C_{emission}$ from energy sectors at farms and slaughterhouses are shown in Table 4.

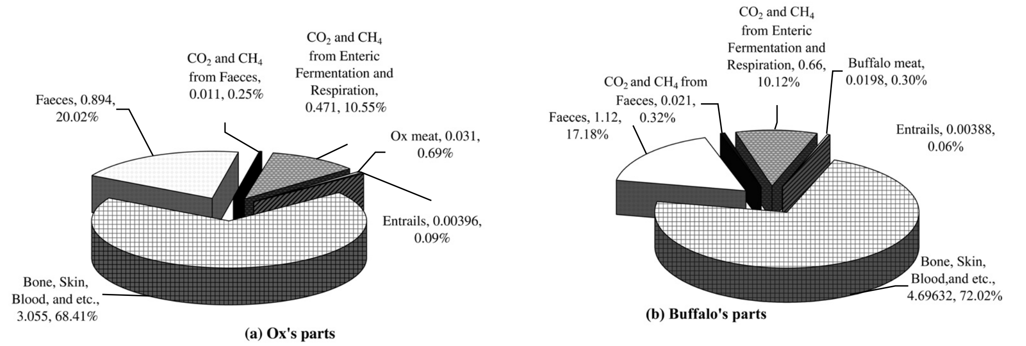


Figure 3. The percentages of carbon contents transferred from grass to ox's parts and buffalo's parts

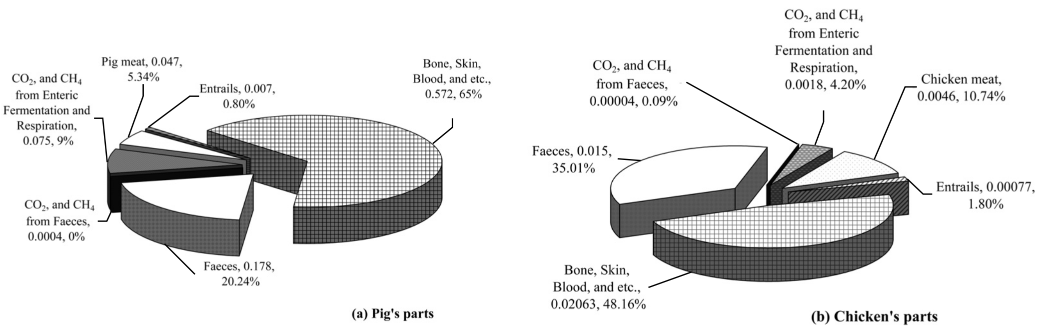


Figure 4. The percentages of carbon contents transferred from animal feed to pig's parts and chicken's parts

Table 3. The gas emission from animals (average ± standard deviation)

Average of gases	Kind of animal	CH_4 (kg.CH_4/head/day)	CO_2 (kg.CO_2/head/day)
Faeces	Ox	0.004 ± 0.002	0.031 ± 0.015
	Buffalo	0.005 ± 0.003	0.062 ± 0.035
	Pig	0.0001 ± 0.0000	0.0010 ± 0.0003
	Chicken	0.000003 ± 0.000002	0.000148 ± 0.000156
Enteric fermentation and respiration	Ox	0.104 ± 0.063	1.440 ± 0.618
	Buffalo	0.127 ± 0.068	2.069 ± 0.942
	Pig	0.0071 ± 0.0074	0.2536 ± 0.1286
	Chicken	0.0000 ± 0.0000	0.0067 ± 0.0000

Table 4. The average of $C_{emission}$ from energy sectors at farms and slaughterhouses (average ± standard deviation)

Average carbon contents from energy sectors (kg.C/head/day)		$C_{emission}$			
		Ox	Buffalo	Pig	Chicken
Farms	Electricity*	0.00 ± 0.01	0.00 ± 0.00	0.02 ± 0.02	0.002 ± 0.00
	Transportation energy**	0.00 ± 0.00	0.01 ± 0.01	0.81 ± 0.85	0.044 ± 0.03
	Engine energy***	0.09 ± 0.13	0.07 ± 0.16	N.D.	N.D.
	LPG*	N.D.	N.D.	N.D.	0.003 ± 0.00
	Total carbon contents	0.10	0.08	0.83	0.049
Slaughterhouses	Electricity*	0.22 ± 0.37	0.12 ± 0.04	0.05 ± 0.04	0.009 ± 0.004
	Transportation energy**	0.30 ± 0.26	0.32 ± 0.39	0.01 ± 0.00	0.0015 ± 0.0016
	Wood and paddy husk	N.D.	N.D.	2.28 ± 1.02	0.1227 ± 0.1708
	Total carbon contents	0.52	0.44	2.34	0.1332
Total carbon emission from farms and slaughterhouses	(kg.C/head/day)	0.62	0.52	3.17	0.1822
	(kg.C/kg. living weight/day)	2.05×10^{-3}	1.14×10^{-3}	31.41×10^{-3}	77.86×10^{-3}

* IPCC (1996) CO_2 emission = 0.18 kg.C/kWh and CO_2 emission from LPG = 3.0102 kg.CO_2/1kg.LPG
** National Transportation Statistics (2000) CO_2 emission = 74.5 kg.CO_2/1 Ton/500 km
*** U.S. EPA, AP-42 (1995) and WHO (1993) CO_2 emission from diesel oil = 2.24 kg.CO_2/L and CO_2 emission from gasoline = 2.10 kg.CO_2/L

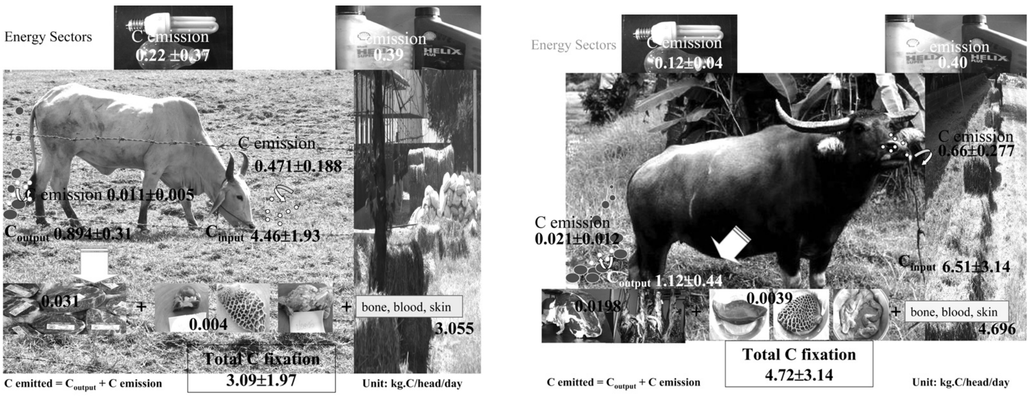
The Relation of Carbon Contents Massflow and Physical Properties of Animal Feed, Meat, and Faeces from Ox, Buffalo, Pig, and Chicken

The carbon contents massflow of ox and buffalo are shown in Figures 5(a) and 5(b) and the carbon contents massflow of pig and chicken are shown in Figures 6(a) and 6(b), respectively. The relation of $C_{emitted}$ and C_{input} (Sig. F<0.05) and $C_{fixation}$ and C_{input} (Sig. F<0.05) are shown in Figures 7(a) and 7(b), respectively. The results showed that the carbon emitted from chicken increased the most environmental problems.

The results also showed that the changes in carbon contents emitted, fixed, input, and emitted from energy used in ton C per year can be illustrated by using the equation from the mass conservation and the numbers of animals as follows:

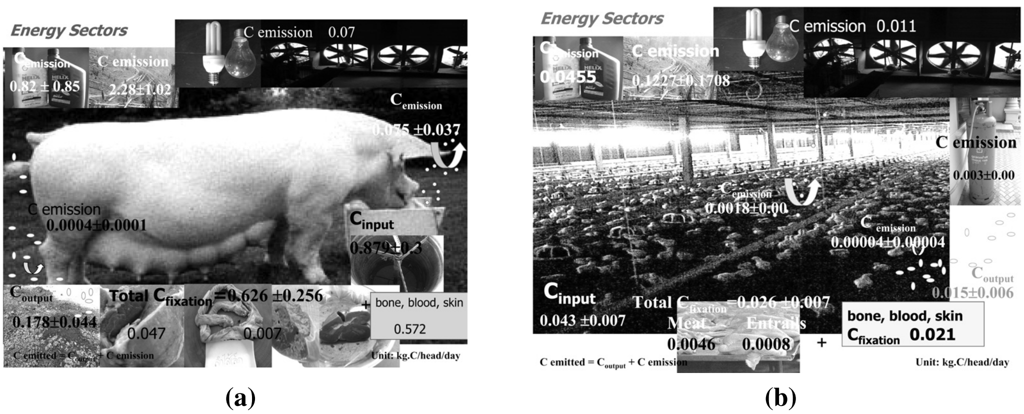
$$\text{C-emitted}_{(animals+energy)} = (0.73)\ \text{Oxen} + (0.85)\ \text{Buffaloes} + (1.25)\ \text{Pigs} + (0.07)\ \text{Chickens} \quad (1)$$

$$\text{C-input} = (1.63)\ \text{Oxen} + (2.38)\ \text{Buffaloes} + (0.32)\ \text{Pigs} + (0.016)\ \text{Chickens} \quad (2)$$



(a) (b)

Figure 5. The carbon mass balance for ox and buffalo meat production
(a) Carbon massflow of ox
(b) Carbon massflow of buffalo



(a) (b)

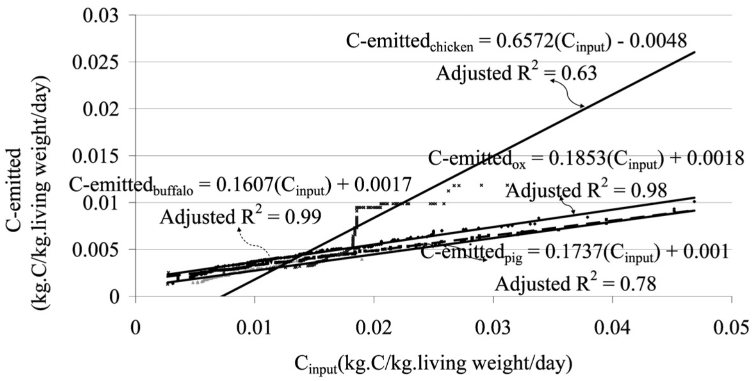
Figure 6. The carbon mass balance for pig and chicken meat production
(a) Carbon massflow of pig
(b) Carbon massflow of chicken

$$\text{C-fixation} = (1.13)\ \text{Oxen} + (1.72)\ \text{Buffaloes} + (0.23)\ \text{Pigs} + (0.0095)\ \text{Chickens} \quad (3)$$

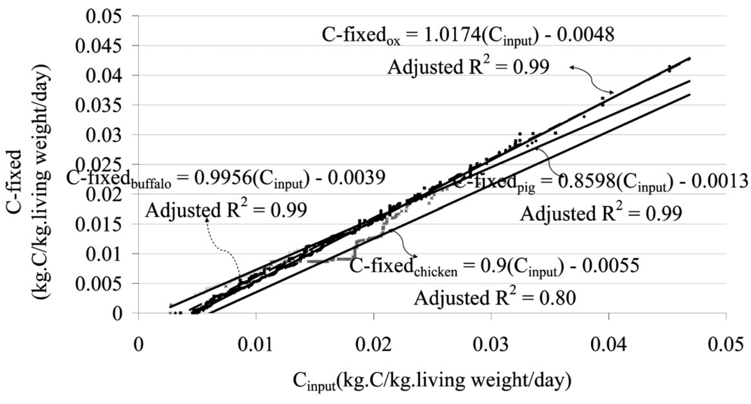
$$\text{C-emission}_{(energy)} = (0.23)\ \text{Oxen} + (0.19)\ \text{Buffaloes} + (1.16)\ \text{Pigs} + (0.0665)\ \text{Chickens} \quad (4)$$

where; C-emitted$_{(animals+energy)}$ is the carbon contents emitted from ox, buffalo, pig, and chicken and the emission from energy used in meat production (ton C/year), C-input is the carbon contents transferred from plants and feed to ox, buffalo, pig, and chicken by feeding (ton C/year), C-fixation is the carbon contents fixed in meat and organs of ox, buffalo, pig, and chicken (ton C/year), C-emission$_{(energy)}$ is the carbon contents emitted from energy using as electricity, LPG, wood or paddy husk, and petroleum of farms and slaughterhouses in meat production (ton C/year). Oxen, Buffaloes, Pigs, and Chickens are the numbers of oxen, buffaloes, pigs, and chickens on farms, respectively (head).

The percentages of moisture, volatile solids, ash, and carbon contents of animal feed, meat, and faeces of animals are shown in Table 5. The lowest percentage of carbon content was



(a)



(b)

Figure 7. The relation of $C_{emitted}$, and $C_{fixation}$ to C_{input} at 95% confidence
(a) The relation of $C_{emitted}$ and C_{input}
(b) The relation of $C_{fixation}$ and C_{input}

in buffalo's faeces (30.14 ± 6.07%) and the highest in buffalo's meat (68.67 ± 0.21%). These percentages of carbon contents from faeces, and meat showed that the buffalo fixed the highest level of carbon in its body.

Conclusions

The study showed that carbon emitted from ox, buffalo, pig, and chicken farms and slaughterhouses was 0.0066, 0.0051, 0.0339, and 0.0851 kg.C/kg. living weight/day, respectively. A buffalo and an ox emitted more carbon than a pig and a chicken but the carbon contents per unit in the energy sectors for sbuffalo and ox meat production were lower than the values for pig and chicken meat production. On the other hand, the $C_{emission}$ of energy used for ox, buffalo, pig, and chicken meat production by farms and slaughterhouses was

Table 5. Physical properties, carbon contents, and the relation of C and VS of feed, meat, and faeces (average ± standard deviation)

Type	Moisture (%)	Volatile solids (%)	Ash (%)	Carbon Contents (%)	Linear regression equations	Coefficient of determination (R^2)
Grass	76.64 ± 7.99	75.20 ± 3.45	24.80 ± 3.45	40.42 ± 1.33	%VS = 3.54 (%C) - 68.59	0.89
Rice straw	7.79 ± 1.39	70.91 ± 2.74	29.81 ± 2.74	40.13 ± 1.47	%VS = 1.54 (%C) + 8.26	0.69
Ox meat	73.05 ± 5.59	83.34 ± 4.20	16.65 ± 4.20	58.99 ± 0.25	%VS = 16.40 (%C) - 884.11	0.94
Ox's faeces	81.12 ± 3.78	62.18 ±10.48	37.82 ±10.48	33.47 ± 5.08	%VS = 2.65 (%C) - 26.35	0.89
Buffalo meat	76.71 ± 1.85	86.61 ± 3.29	13.39 ± 3.29	68.67 ± 0.21	%VS = 14.90 (%C) - 936.50	0.88
Buffalo's faeces	81.98 ± 4.42	54.45 ±11.23	45.55 ±11.23	30.14 ± 6.07	%VS = 2.31 (%C) - 14.93	0.95
Pig's feed	10.48 ± 2.22	70.28 ± 2.42	29.72 ± 2.42	45.02 ± 2.05	%VS = 0.93 (%C) + 28.43	0.62
Pig meat	68.74 ± 5.63	82.62 ± 3.67	17.38 ± 3.67	48.00 ± 5.09	%VS = 0.70 (%C) + 48.97	0.94
Pig's faeces	67.71 ± 5.54	61.30 ± 3.40	38.7 ± 3.4	35.98 ± 1.83	%VS = 1.78 (%C) - 2.78	0.92
Paddy husk	11.12 ± 1.01	60.67 ± 5.45	39.33 ± 5.45	35.56 ± 3.33	%VS = 1.64 (%C) + 2.99	0.95
Chicken's feed	10.45 ± 1.25	72.82 ± 2.07	27.18 ± 2.07	44.06 ± 4.52	%VS = 0.40 (%C) + 55.01	0.78
Chicken meat	65.71 ± 6.57	84.37 ± 4.01	15.63 ± 4.01	48.40 ± 6.21	%VS = 0.59 (%C) + 55.97	0.83
Chicken's feed	61.51 ± 22.31	66.39 ± 9.16	33.61 ± 9.16	34.07 ± 6.13	%VS = 0.97 (%C) + 33.23	0.42

30.72%, 22.40%, 92.60%, and 91.54% of the total carbon emitted from animal and energy sectors in meat production. Carbon fixation in meat and organs of ox, buffalo, pig, and chicken was 0.0102, 0.0104, 0.0062, and 0.0111 kg.C/kg. living weight/day, respectively. Carbon content values were calculated by mass balance. The rate of carbon massflow from grass and feed to ox, buffalo, pig, and chicken was 0.0148, 0.0143, 0.0087, and 0.0184 kg.C/kg. living weight/day, respectively.

Furthermore, this study showed that the ratio of the carbon fixed in meat and organs of ox, buffalo, pig, and chicken to the carbon contents in grass and feed was 0.69, 0.72, 0.71, and 0.60, respectively. The ratio of the total carbon emitted per head per day to the total carbon contents per head per day in grass and feed used for feeding was 0.31, 0.28, 0.28, and 0.39, respectively. The ratio of $C_{emitted}$ to C_{input} shows that the contribution to environmental problems from buffalo is the lowest. The ratio of the total carbon emitted to the carbon fixation of ox, buffalo, pig, and chicken was 0.45, 0.38, 0.40, and 0.65, respectively. It can be concluded that the carbon contents emitted from chicken increases the most environmental problems (Table 6).

Acknowledgements

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 and Suranaree University of Technology. We thank our advisor, teachers, consulting persons and our families for critical and helpful comments to this research.

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Table 6. The ratio of C_{input}, $C_{fixation}$, $C_{emitted}$ from feeding in meat production

Kind of animal	C_{input}	$C_{fixation}$	$C_{emitted}$	The percentage of			
	(kg.C/kg. living weight/day) x 10^{-3}			$C_{fixation}$ / C_{input}	$C_{emitted}$ / C_{input}	$C_{emitted}$ / $C_{fixation}$	(C_{input} - $C_{emitted}$) / C_{input}
Ox	14.76	10.22	4.57	69.04	30.96	44.72	69.04
Buffalo	14.27	10.35	3.95	72.32	27.68	38.16	72.32
Pig	8.71	6.20	2.48	71.53	28.47	40.00	71.53
Chicken	18.38	11.11	7.27	60.45	39.55	65.44	60.45

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