Comparison of Carbon Emitted Factors from Ox and Buffalo Farms and Slaughterhouses in Meat Production

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Abstract

The carbon budget of oxen and buffaloes during meat production were studied to develop carbon emitted factors from ox and buffalo farms and slaughterhouses in ox and buffalo meat production; to investigate the rate of carbon massflow from plants to oxen and buffaloes in the food chain and to study the carbon emission in energy patterns from electric energy and petrol that was used in meat production in Nakhon Ratchasima province. The study showed that the carbon emitted per unit from ox and buffalo farms and slaughterhouses in ox and buffalo meat production were 2.00 and 2.32 kg C $head^{-1}\ d^{-1}$, respectively. The carbon fixation in meat and organs, of oxen and buffaloes was 3.09 and 4.72 kg C $head^{-1}\ d^{-1}$, respectively and the rate of carbon massflow from grass, and the energy used for electricity, and petroleum was 5.15 and 7.10 kg C $head^{-1}\ d^{-1}$, respectively. This study also showed the ratio of the carbon fixation in ox or buffalo meat and organs to the sum of carbon contents in grass, and carbon contents from electric energy and petrol used in ox and buffalo meat production was 0.60 and 0.66, respectively. The ratio of total carbon emitted per unit to total carbon contents per unit in grass and energy used in ox and buffalo meat production was 0.39 and 0.33, respectively. The ratio of total carbon emitted per day to carbon fixation per day in meat and organs of an ox and a buffalo was 0.65 and 0.49, respectively. Ox production produced more environmentally harmful carbon than buffalo production. For the same quantity of meat production it can be suggested that decreasing ox meat production and increasing buffalo meat production can decrease the environmental problems. The carbon contents changes emitted in meat production in ton C per year from ox and buffalo farms and slaughterhouses in Nakhon Ratchasima province can be predicted by using the equation from simple linear regression analysis and least square method as follow; $C\text{-emitted}_{ox\ meat} = 38814(year) + 125824$ ($R^2 = 0.78$) and $C\text{-emitted}_{buffalo\ meat} = 1568.7(year) + 50931$ ($R^2 = 0.92$) where; year is year of our Lord in 2001-2010.

Keywords: carbon massflow, carbon emission, ox, buffalo

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 (Intergovernmental Panel on Climate Change, 1995) with CH_4 being 23 times more potent than CO_2 (Intergovernmental Panel on Climate Change, 2001). Ox and buffalo are herbivores 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 it 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 and carbon transfer to herbivores' energy use for meat production.

Materials and Methods

The primary objective of this study was to develop carbon emitted factors for ox and buffalo farms and slaughterhouses in ox and buffalo meat production. To accomplish this we studied the rate of carbon massflow from plants to ox and buffalo, and included the carbon emissions from electricity and petroleum used during meat production in Nakhon Ratchasima.

We studied ox and buffalo farms and slaughterhouses, in 32 districts of Nakhon Ratchasima province (Figures 1 and 2, respectively). Nakhon Ratchasima province has an agricultural area of 12,469.46 square kilometers and is the largest area of ox and buffalo farms in Thailand (Center for Agricultural Information, Office of Agricultural Economics, 2004). Grass and feed for oxen and buffaloes, plus their meat and faeces were collected and transferred to the laboratory at Suranaree University of Technology for measurements. The analytical methods are shown in Table 1.

Size of Samples

The numbers of farms, of oxen and buffaloes, in each district were calculated by determining the number of ox and buffalo farms and the number of oxen and buffaloes in the province at 95% confidence level (Yamane, 1973; Cavana et al., 2001). According to the population of the study, the totals of population study of the ox farms and buffalo farms were 56,386 and 12,618 farms, respectively. Therefore, the researcher calculated the sample group 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 ox farms for the study has been calculated according to the recommendation as follows:

$$n = 56386 / \{1+56386*(0.05)^2\} = 398 \text{ ox farms}$$

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

Property	Analytical method
Moisture content	By weighing sample after oven drying at 103-105°C for 24 h (Manlay et al., 2004).
Carbon content (C)	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).

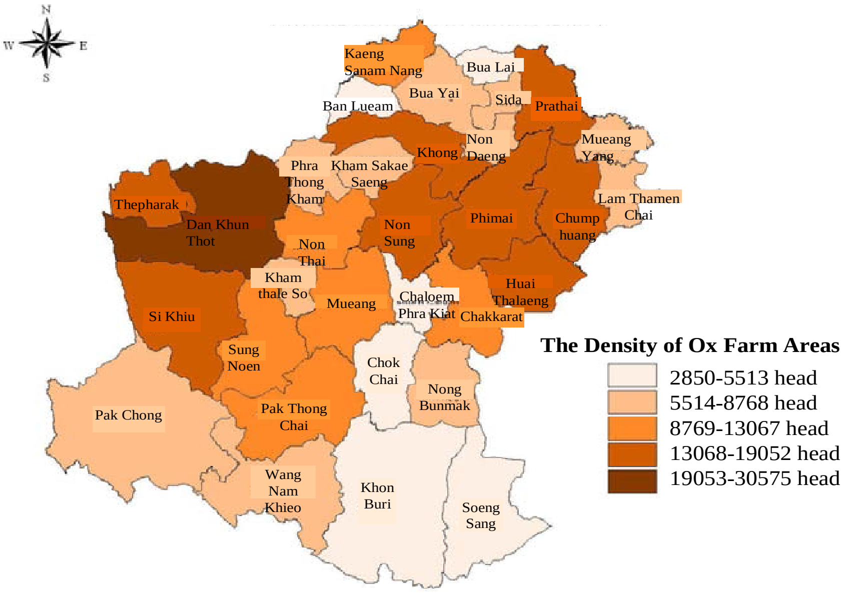

Figure 1 Ox farm areas in Nakhon Ratchasima (Department of Livestock Development, 2005).

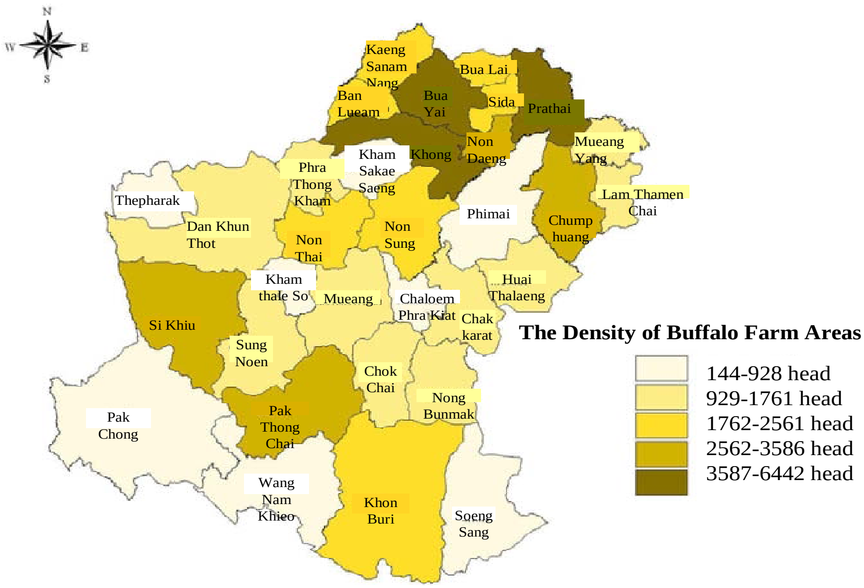

Figure 2 Buffalo farm areas in Nakhon Ratchasima (Department of Livestock Development, 2005).

With N = 56386, e = 5% (at 95% confidence level), hence the sample size is 398 respondents. The results showed that sample size were 398 ox farms, 390 buffalo farms, and 17 slaughterhouses which calculated by Taro Yamane formula. Taro Yamane's formula also used to obtain the sample size of oxen, and buffaloes to be totalled 400 oxen from ox farms, and totalled 398 buffaloes from buffalo farms.

Results and Discussion

The Rate of Carbon Contents Massflow and the Carbon Emitted Factors

This study determined that the rate of carbon massflow from grass for feeding to the biomass and the faeces of oxen and buffaloes (C_{input}). The rate of transference of carbon contents from plants to ox and buffalo were 4.46 ± 1.93 and 6.51 ± 3.14 kg C head^{-1} d^{-1}, (average ± standard deviation) respectively (Table 2). Table 2 also shows the carbon fixation factors of ox and buffalo were 3.09 ± 1.97 and 4.72 ± 3.14 kg C head^{-1} d^{-1}, respectively. Carbon contents were calculated by mass balance. The transference of carbon contents (C_{input}) minus the carbon contents emitted in faeces, enteric fermentation, and respiration ($C_{emitted}$) were the carbon mass fixed in the body ($C_{fixation}$). The carbon emitted factors for ox and buffalo were 1.38 ± 0.36 and 1.80 ± 0.51 kg C head^{-1} d^{-1}, respectively. Table 2 also shows the ratio of $C_{emitted}$ per day from ox and buffalo to C_{input} per day of ox and buffalo by feeding was 30.94% and 27.65%, respectively. This ratio of $C_{emitted}$ to C_{input} shows that the contribution to environmental problems from buffalo is lower than for ox.

Figures 3 and 4 show the percentages of CH_4 and CO_2 emitted from ox and buffalo. Comparison of the ratio of CH_4 to CO_2 emitted from faeces, enteric fermentation and respiration of ox was greater than the value for buffalo. Therefore ox was contributing more to global climate change than buffalo.

CO_2 and CH_4 gases which were emitted from faeces, enteric fermentation and respiration of ox and buffalo are shown in Table 3.

Table 4 shows the ratio of meat, entrails, skin, blood, and bone to weight of ox and buffalo that were killed in slaughterhouses.

Figures 5 and 6 show the ratio of the carbon contents transferred to ox and buffalo by feeding. The carbon mass fixed in the biomass of ox and buffalo was 69.18% and 72.38%, respectively, and that emitted from faeces, enteric fermentation and respiration of ox and buffalo was 30.82% and 27.62%, respectively. Carbon emitted which contribute to environmental problems show that buffalo encourage less global climate change than ox because buffalo fixed the carbon contents in its body more efficiently than ox.

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

Kind of animal			Ox	Buffalo
C_{input} transferred from plant by feeding (kg C head^{-1} d^{-1})			4.46 ± 1.93	6.51 ± 3.14
$C_{fixation}$ (mass balance) (kg C head^{-1} d^{-1})	Meat		0.031	0.0198
	Entrails		0.004	0.0039
	Bone, skin, blood and etc.		3.055	4.696
	Total $C_{fixation}$		3.09 ± 1.97	4.72 ± 3.14
$C_{emitted}$ (kg C head^{-1} d^{-1})	Dried Faeces (C_{output})		0.894 ± 0.31	1.12 ± 0.44
	$C_{emission}$ of CO_2 and CH_4 gases	Faeces	0.011 ± 0.005	0.021 ± 0.012
		Enteric fermentation and respiration	0.471 ± 0.188	0.66 ± 0.277
	Total $C_{emitted}$ from animal		1.38 ± 0.36	1.80 ± 0.51

Table 3 The average of CH_4 and CO_2 emission from ox and buffalo in farms in Nakhon Ratchasima (average ± standard deviation).

Kind of animal	Average of gases (kg head^{-1} d^{-1})	CH_4	CO_2
Ox	Faeces	0.00 ± 0.00	0.03 ± 0.01
	Enteric fermentation and respiration	0.10 ± 0.06	1.44 ± 0.62
Buffalo	Faeces	0.01 ± 0.00	0.06 ± 0.03
	Enteric fermentation and respiration	0.13 ± 0.07	2.07 ± 0.94

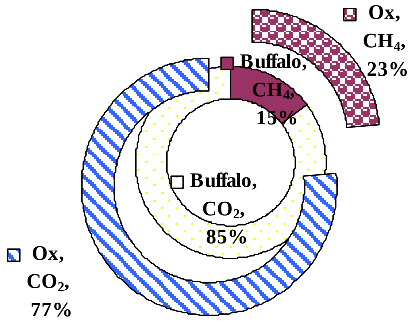

Figure 3 The percentages of CH_4, and CO_2 gases from faeces of ox and buffalo.

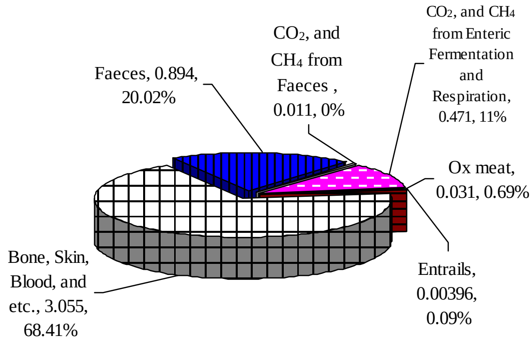

Figure 5 The percentages of carbon contents were transferred from grass to ox's parts.

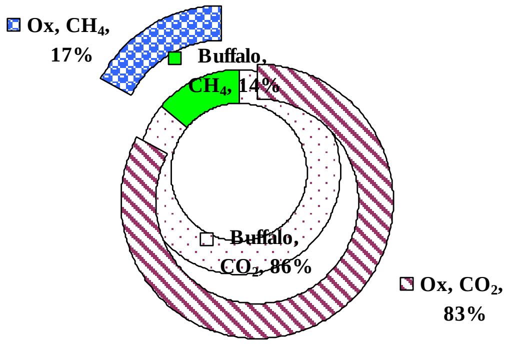

Figure 4 The percentages of CH_4, and CO_2 gases from enteric fermentation and respiration of ox and buffalo

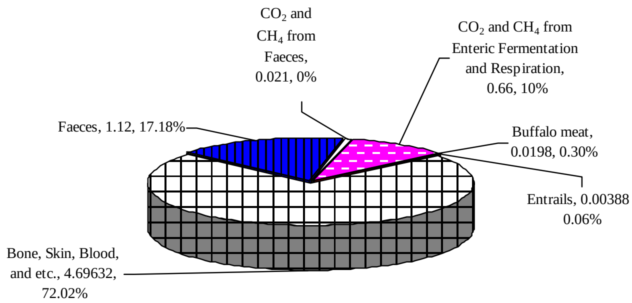

Figure 6 The percentages of carbon contents were transferred from grass to buffalo's parts.

Carbon Contents Emission from Energy Sectors for Meat Production

The ox and buffalo farms in Nakhon Ratchasima province used little energy for feeding. The first sector was electric light 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 C_{input} and $C_{emission}$ per unit of all 3 energy sectors at ox farms were 0.12 ± 0.16 and 0.10 ± 0.14 kg C $head^{-1}$ d^{-1}, respectively. The C_{input} and $C_{emission}$ per unit of all 3 energy sectors at buffalo farms were 0.10 ± 0.19 and 0.08 ± 0.16 kg C $head^{-1}$ d^{-1}, respectively. On the other hand, the slaughterhouses in Nakhon Ratchasima used energy for electric light and delivering meat from slaughterhouses to markets with C_{input} and $C_{emission}$ per unit of energy used by slaughterhouses being 0.57 ± 0.47 and 0.52 ± 0.44 kg C $head^{-1}$ d^{-1}, respectively. The C_{input} and $C_{emission}$ per unit of energy used for buffalo meat production by slaughterhouses was 0.49 ± 0.47 and 0.44 ± 0.40 kg C $head^{-1}$ d^{-1}, respectively. The result of carbon contents per unit in meat production are shown in Table 5.

Carbon Massflow of Animals and Energy Sectors in Meat Production

The result of the carbon massflow from oxen and buffaloes is shown in Figures 7 and 8, respectively. The results also showed that the carbon contents emitted from ox increases environmental problems more than buffalo (Table 6).

The comparison of C_{input} and $C_{emission}$ from energy sectors, C_{input} from plant by feeding, C_{output} and $C_{emission}$ (gases) from animals, and the different carbon contents per unit between C_{output} from the faeces and $C_{fixation}$ of ox and buffalo are shown in Figure 9. Figure 9 shows the differences between carbon contents transferred to animals by feeding

Table 4 The percentage ratio of meat and entrails of ox and buffalo that were killed in slaughterhouses in Nakhon Ratchasima (average ± standard deviation).

Kind of animal	Ox	Buffalo
Weight before killing (kg head^{-1})	268.74 ± 101.38	337.73 ± 66.91
Ratio of meat to weight before killing (%)	46.55 ± 11.96	34.65 ± 7.14
Ratio of entrails to weight before killing (%)	8.52 ± 2.61	8.32 ± 1.06
Ratio of skin, blood, bone, and etc. to weight before killing (%)	44.93	57.03

Table 5 The average of C_{input} and $C_{emission}$ from energy sectors of ox and buffalo farms and slaughterhouses (average ± standard deviation).

Average carbon contents from energy sectors (kg C head^{-1} d^{-1})		C_{input}		$C_{emission}$	
		Ox	Buffalo	Ox	Buffalo
Farms	Electricity[1/]	0.00 ± 0.01	0.00 ± 0.00	0.00 ± 0.01	0.00 ± 0.00
	Transportation energy[2/]	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.01 ± 0.01
	Engine energy[3/]	0.11 ± 0.16	0.09 ± 0.19	0.09 ± 0.13	0.07 ± 0.16
	Total carbon contents	0.12 ± 0.16	0.10 ± 0.19	0.10 ± 0.14	0.08 ± 0.16
Slaughterhouses	Electricity	0.22 ± 0.37	0.12 ± 0.04	0.22 ± 0.37	0.12 ± 0.04
	Transportation energy	0.35 ± 0.30	0.38 ± 0.46	0.30 ± 0.26	0.32 ± 0.39
	Total carbon contents	0.57 ± 0.47	0.49 ± 0.47	0.52 ± 0.44	0.44 ± 0.40
Total carbon contents of farms and slaughterhouses		0.69	0.59	0.62	0.52

1/ Pollution Control Department (2003) CO_2 emission = 0.18 kg C/kWh.
2/ National Transportation Statistics (2000) CO_2 emission = 74.5 kg CO_2 t^{-1}500 km^{-1}.
3 U.S. EPA, AP-42 (1995) and WHO (1993) CO_2 emission from diesel oil = 0.61 kg C L^{-1} and CO_2 emission from gasoline = 0.57 kg C L^{-1}.

Table 6 The ratio of C_{input}(plant+energy), $C_{fixation}$, $C_{emitted}$(animal+energy) from meat production.

Kind of animal	C_{input} (plant+energy)	$C_{emitted}$ (animal+energy)	Ratio				
	(------------- kg C head^{-1} d^{-1}	----------)	C_{meat}/C_{plant}	$C_{fixation}/C_{input}$	$C_{emitted}/C_{input}$	$C_{emitted}/C_{fixation}$	$C_{fixation}/C_{plant}$
Ox	5.15	2.00					
Buffalo	7.10	2.32	0.25	0.66	0.33	0.49	0.725

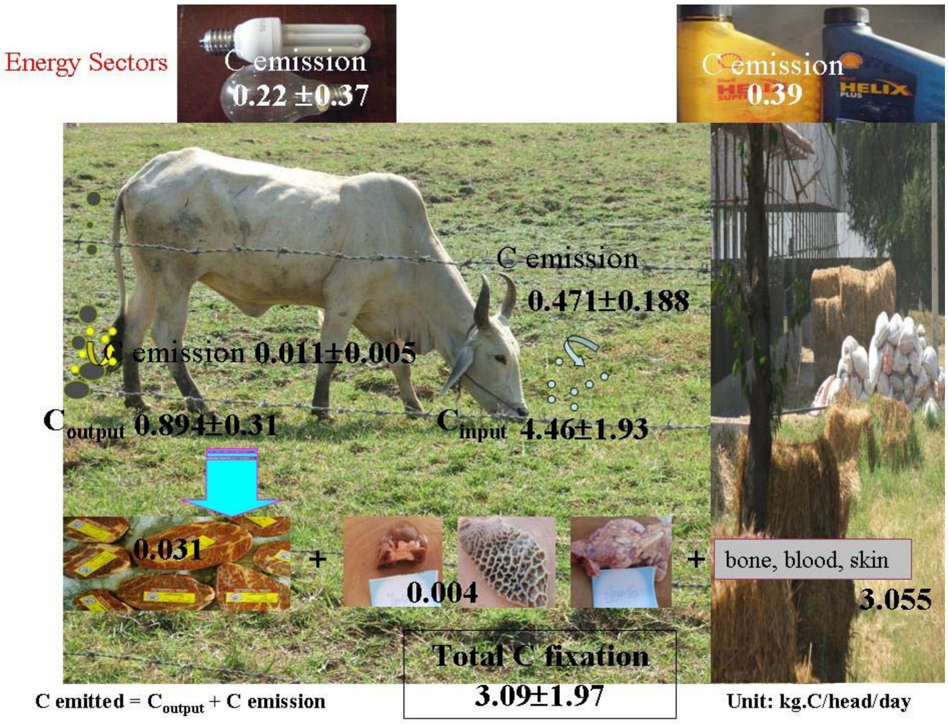

Figure 7 The conclusion of carbon mass balance for ox meat production.

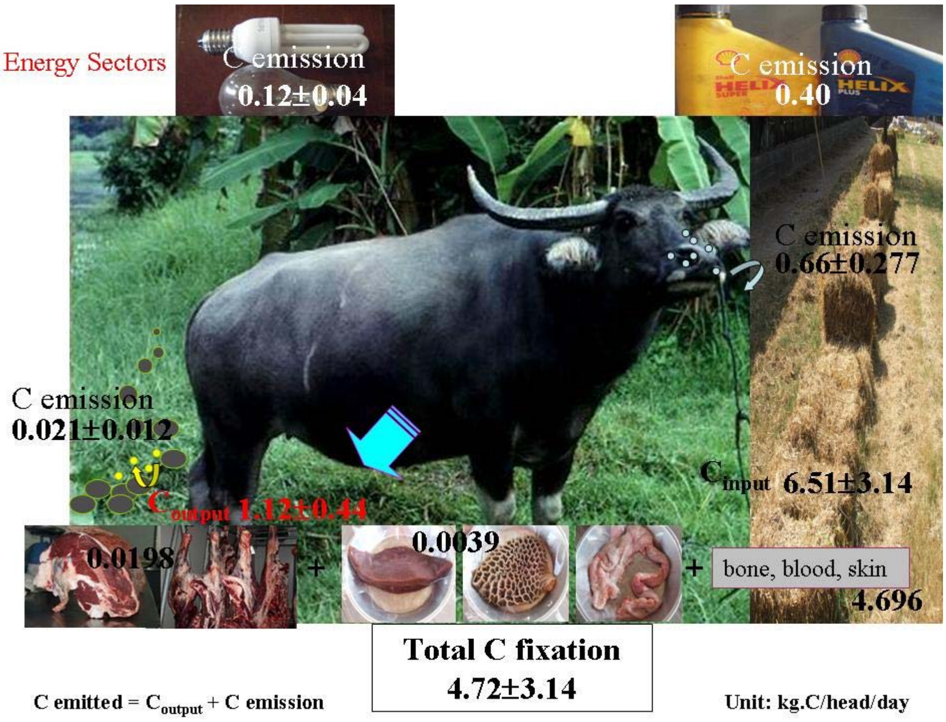

Figure 8 The conclusion of carbon mass balance for buffalo meat production.

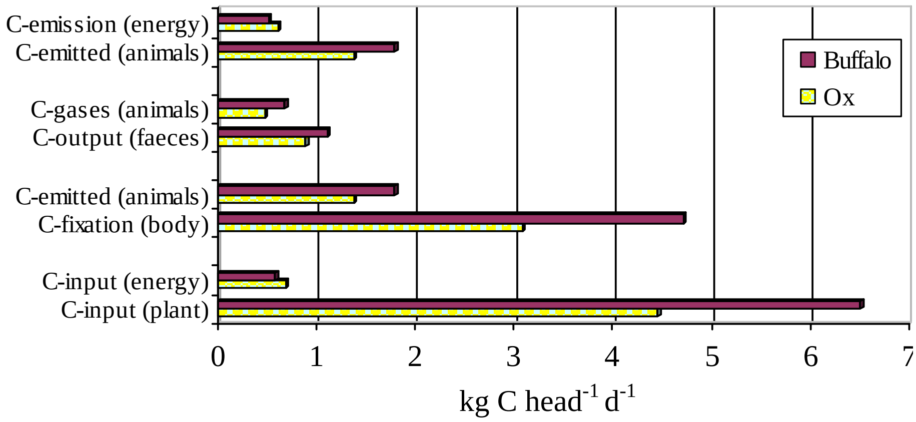

Figure 9 The comparison of the different carbon contents in each pattern of meat production.

and from animals to environment and carbon contents from energy used in electricity and petrol. The results show that the carbon contents in energy pattern are less important for meat production.

Carbon Contents and Physical Properties of Animal Feed, Meat, Entrails, and Faeces from Ox and Buffalo

The weight measurements of ox and buffalo on farms found that oxen were 61-608 kg $head^{-1}$ at 0.17-14.84 years old and buffaloe 63-861 kg $head^{-1}$ at 0.29-20 years old. Figure 10 showed the relationship of the weight of oxen and buffaloes with age, as follows: $weight_{ox} = 93.231 \ln(age_{ox}) + 239.87$ ($R^2 = 0.72$) and $weight_{buffalo} = 154.8 \ln(age_{buffalo}) + 254.4$ ($R^2 = 0.69$). The results showed that oxen fixed carbon contents more than buffaloes in the first year but buffaloes fixed carbon more than oxen after one year of age.

Table 7 shows the average weights for animal food, faeces and animals at farms. The ratio of ox's faeces weight to ox weight and the ratio of buffalo's faeces weight to buffalo weight were 4.72% and 4.56%, respectively.

The percentages of moisture, volatile solids, ash, and carbon contents of animal feed, meat, entrails, and faeces are shown in Table 8. The percentages of carbon contents of buffalo's faeces were 30.14% lower than the value of ox's faeces. These percentages of carbon contents from faeces, entrails, and meat showed that the buffalo fixed carbon in its body more efficiently than the ox.

Table 7 The average weight of oxen and buffaloes, faeces, and animal food from farms in Nakhon Ratchasima (average ± standard deviation).

Kind of animal	Animal weight (kg $head^{-1}$)	Faeces weight (kg $head^{-1}$ d^{-1})	Animal food weight (kg $head^{-1}$ d^{-1})
Ox	302.25 ± 100.72	14.27 ± 4.94	11.06 ± 5.07
Buffalo	456.10 ± 134.38	20.79 ± 8.08	16.01 ± 7.77

Table 8 Physical properties, carbon contents, and the linear equations of the carbon contents to volatile solids of animal feed, meat, entrails, and faeces from ox and buffalo farms (average ± standard deviation).

Type	Moisture	Volatile solid	Ash	Carbon content	Linear regression equation	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
Ox's entrails[1/]	80.44 ± 3.44	85.24 ± 1.79	14.76± 1.79	56.02 ± 6.45	%VS =0.03(%C) + 83.52	0.30
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) - 14.933	0.95
*Buffalo's entrails	79.46 ± 3.28	85.70 ± 2.05	14.30± 2.05	63.61 ± 9.36	%VS =-0.08(%C) + 90.63	0.34

[1/] The average of each entrails of ox and buffalo.

Forecasting Trends of Carbon Emission from Meat Production

The future trend of carbon emitted from meat production at ox and buffalo farms and slaughterhouses is shown in Figure 11. The graph predicts from carbon emitted for ox meat production to be 2.00 kg C $head^{-1}$ d^{-1} or 0.73 t C $head^{-1}$ y^{-1} and for buffalo meat production to be 2.32 kg C $head^{-1}$ d^{-1} or 0.85 t C $head^{-1}$ y^{-1}, respectively. These values are based on oxen and buffaloes statistics from 2001-2006 in Nakhon Ratchasima province. The results showed that the changes in carbon contents emitted in meat production (ton C per year) from ox and buffalo farms and slaughterhouses in Nakhon Ratchasima province. 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; $C\text{-emitted}_{ox\ meat}$ = 38814(year) + 125824 (R^2 = 0.78) and $C\text{-emitted}_{buffalo\ meat}$ = 1568.7(year) + 50931 (R^2 = 0.92) where; year is year of our Lord in 2001-2010. Environmental problems could be decreased by decreasing ox meat production and increasing buffalo meat production (Thanee et al., 2008).

Conclusions

The study showed that carbon emitted factors for ox and buffalo farms, and for slaughterhouses were 2.00 and 2.32 kg C $head^{-1}$ d^{-1}, respectively. Buffalo emitted more carbon than ox but the carbon contents per unit in the energy sectors for buffalo meat production were lower than the values for ox meat production. Carbon fixation factors in meat and organs of ox and buffalo were 3.09 and 4.72 kg C $head^{-1}$ d^{-1}, respectively. The rate of carbon massflow from grass, and from energy used in transportation and killing of ox and buffalo were 5.15 and 7.10 kg C $head^{-1}$ d^{-1}, respectively.

Furthermore, this study showed that the ratio of the carbon fixed in meat and organs to the sum of carbon contents in grass, and carbon contents in electricity and petrol used were 0.60 and 0.66, respectively. The ratio of the total carbon emitted per unit to the total carbon contents per unit in grass and energy used for meat production were 0.39 and 0.33, respectively. The ratio of the total carbon emitted per unit to the carbon fixation of ox and buffalo were 0.65 and 0.49, respectively.

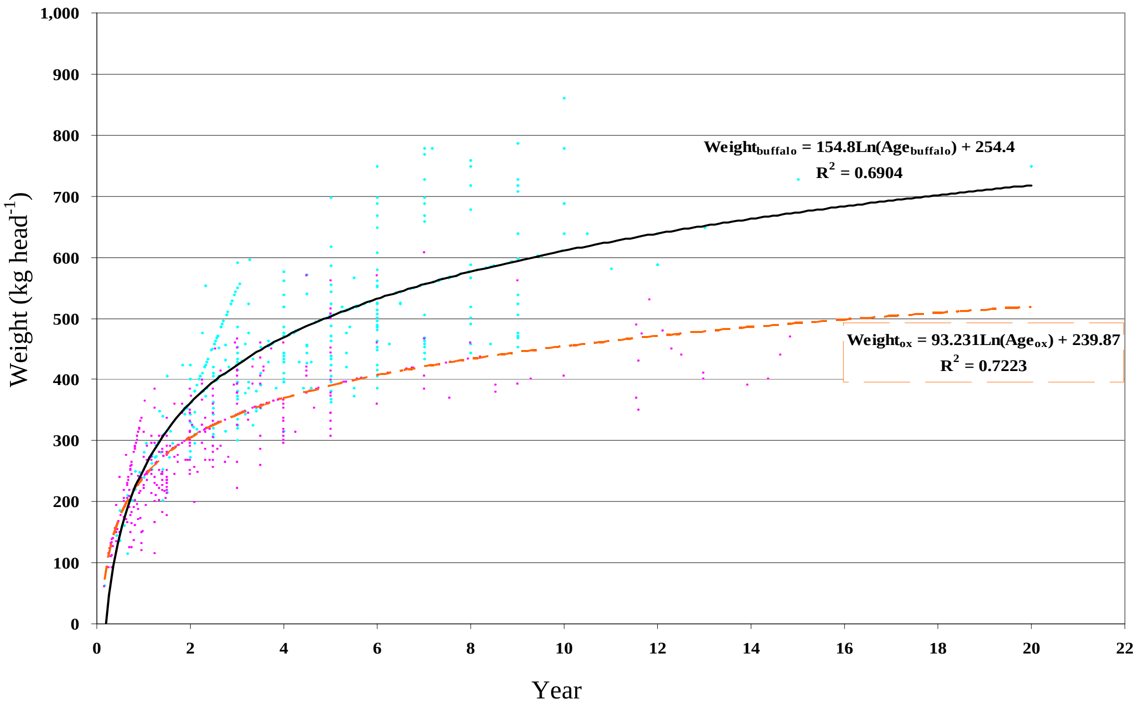

Figure 10 The relation of ox and buffalo weights with their age.

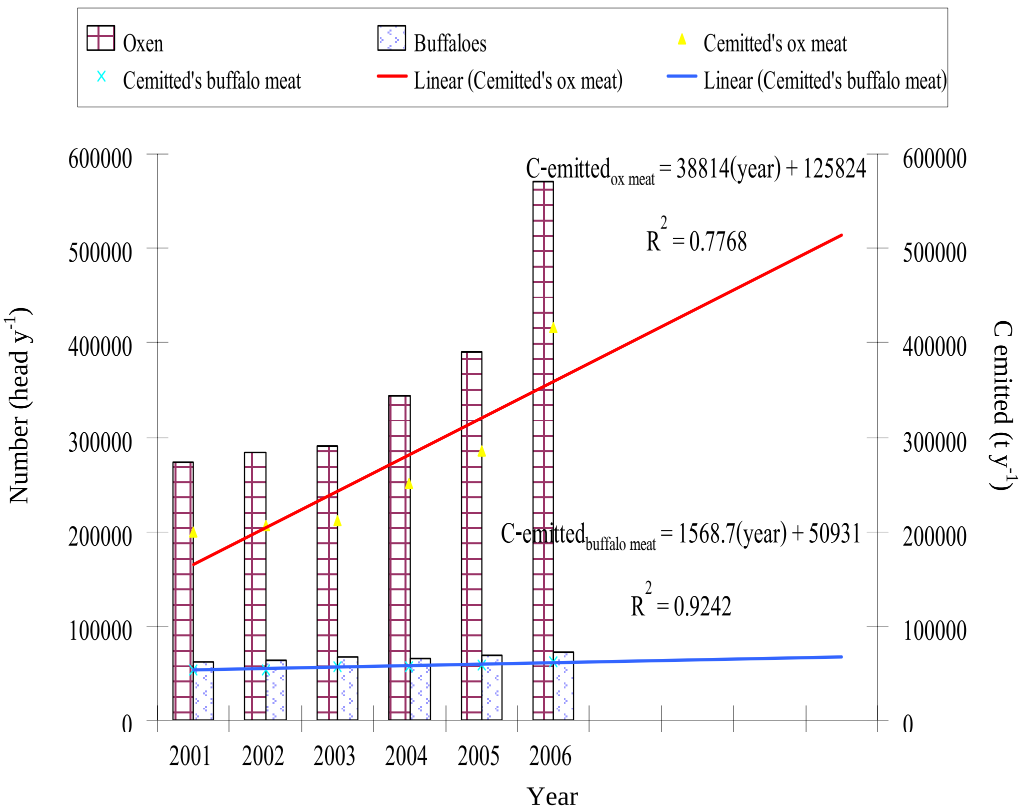

Figure 11 The future trend of carbon contents emitted from oxen and buffaloes meat Production in Nakhon Ratchasima.

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