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# Local emission factors estimates for methane emission from cattle enteric fermentation using IPCC tier-2 methodology

**Azizi, A.A.[*1], Mardhati, M.[1], Mohd Fairuz, M.S.[2], Shaidatul Azdawiyah, A.T.[2], Nurul Ain, A.B.[2], Fauzi, J.[2], Mohamad Hariz, A.R.[2] and Reisinger[3], A.**
[1]Animal Science Research Center, [2]Biodiversity and Environment Research Center, Malaysian Agricultural Research and Development Institute (MARDI), Serdang, Selangor,
[3]New Zealand Agricultural Greenhouse Gas Research Center, Wellington, New Zealand
*Corresponding author: aziziazmin@mardi.gov.my

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## Abstract

Understanding the magnitude of consequences of climate change caused by greenhouse gases (GHG) emissions largely relies on GHG inventory stocktaking and emission estimates that aggregate activity data and emission factors (EF). For that matter, a specific EF to calculate methane ($CH_4$) emission from mature beef cattle enteric fermentation has been devised using IPCC Tier-2 methodology for breeding cows and breeding bulls based on local production parameters, which in this case, from local beef breed of Brakmas cattle. EF generated for breeding cows and breeding bulls were 51.6 and 65.7 kg $CH_4$/animal/year, respectively. The values are higher than the default IPCC value of 47 kg $CH_4$/animal/year for similar region. Average value for the generated EF, which was 58.65 kg $CH_4$/animal/year, with an uncertainty range of ±30% was used in the calculation of emission using IPCC Tier-1 methodology. The use of this value resulted in 24.8% higher estimates than when using the default IPCC EF. This EF value is suggested for use in emission estimates for the national GHG inventory reporting.

Keywords: emission factor, Brakmas cattle, methane emission, greenhouse gas

## Introduction

It is widely recognized that greenhouse gases (GHG) emission are the primary cause of climate changes and its impacts on human and natural systems (IPCC, 2014). The livestock sector particularly ruminants are a significant source of global methane ($CH_4$) emissions (Lassey, 2007). Globally, the sector contributes 18% (7.1 billion tonnes $CO_2$ equivalent) of global greenhouse gas emissions. Although this accounts for only 9% of global $CO_2$, it generates 65% of human-related nitrous oxide ($N_2O$) and 35% of methane global output ($CH_4$).

Methane is one of the important greenhouse gases which the Intergovernmental Panel on Climate Change stated as 25 times the Global Warming Potential (GWP) of $CO_2$ (IPCC, 2007), an increase from an earlier value of 21 of the previous guideline (IPCC, 1997) .

Methane is generated from ruminants' enteric fermentation process in which the amount is driven primarily by the number of animals, the type of digestive system, and the type and amount of feed consumed (Ulyatt *et al.*, 2000). Enteric fermentation process in cattle’s rumen is the largest contributor to methane emission in the livestock sector (Steinfeld *et al.*, 2006).

Methane is a major inefficiency indicator in animal production systems, in which 2% to 12% of gross energy intake is lost as methane through methanogenesis in the cattle's rumen (Johnson and Johnson, 1995). As the demand for livestock products (mainly meat and dairy products) would continue to increase, mitigation options are essential to address future methane emissions. Most mitigation interventions can provide both environmental and economic co-benefits by increasing energy efficiency (Kandel *et al.*, 2015). Efficient practices and technologies can boost productivity and thus contribute to food security and poverty alleviation. The national methane emission from enteric fermentation accounts for 2% of total emission in 2011. Most of these emissions came from large ruminant production (NRE, 2015).

Malaysia livestock population in 2016 showed a large increase in poultry production (at nearly 185%), while the ruminant industry grew at 10% and 15% for cattle and small ruminant, respectively compared to 1996. The transformation of the Malaysian livestock industry of beef, buffalo and dairy cattle as outlined in the Fourth National Agrofood Policy (NAP4) is expected to increase the beef and buffalo meat annual production by 5% with an increase in self-sufficiency level (SSL) by 1.3%. One of the ways to improve production of beef is to enhance the efficiency and productivity of local breeds of cattle such as Brakmas and Kedah-Kelantan especially through integration under oil palm plantation (Johari, 2005), as Malaysia is the second largest world producer of the palm oil in 2012 (Ranjeeta, 2013; FAO, 2007) .

Global consumption of meat, milk and eggs has increased gradually over the years, in parallel with the increase in per capita income especially in East and South East Asia (Devendra, 2007; Boland *et al.*, 2013), human population growth and urbanization (Schwarzer *et al.*, 2012). By 2020, Malaysia's fresh meat production is expected to increase to 2.1 million metric tons and milk at 118 million litters (MOA, 2011). With the increment of the SSL and livestock population and production, future methane emission for beef (non-dairy) cattle is also projected to increase by 0.39% annually from 1030 Gg $CO_2$ eq in 2015 to 1092 Gg $CO_2$ eq in 2030, based on compound annual growth rate (CAGR) of non-dairy cattle calculated using published population data. Policymakers will need to truly understand the emission and devise an impactful mitigation measure to cope with the ever-increasing emission especially from methane.

As future methane emissions will be affected through the improvements in management practices and changes in demand for livestock products (mainly meat and dairy products), developing an understanding of methane emissions largely relies on bottom-up approaches that aggregate activity data and local emission factors (EF). Livestock $CH_4$ inventory of ASEAN countries, including Malaysia, is still thought to be highly uncertain due to lack of detailed statistical data and local EF measurements.

The Intergovernmental Panel on Climate Change (IPCC) Guidelines recommend two general methods to estimate emissions: Tier-1 and Tier-2. The Tier-1 method applies default EF provided by IPCC as a general approach to estimate $CH_4$ emissions from livestock. However, the default EF often results in less accurate emission reports. The Tier-2 EFs are based on country-specific data on nutrient requirements, feed intake, and the methane conversion rate for the specific feed type which result in more accurate emission reports (Ulyatt *et al.*, 2000). More accurate reports would mean more accurate emission estimates and help policymakers to devise a better mitigation plan for a particular sub-sector, which in this case, ruminant livestock.

The objective of this study is to generate a country specific EF of $CH_4$ emission from beef cattle enteric fermentation. The EF generated would then be used in future emission estimates and country GHG Inventory reports to the United Nations Framework Convention on Climate Change (UNFCCC).

## Materials and Methods

*Calculation of Emission Factor*

The formula for the calculation of EF as in Equation 10.21 is described in IPCC 2006 Guidelines (IPCC, 2006) under Emissions from Livestock and Manure Management. Related parameters and calculations were also derived from similar guidelines. The formula is as follows:

$CH_4$ emission factors for enteric fermentation from a livestock category

$$EF = \left[ \frac{GE \bullet \left( \frac{Y_m}{100} \right) \bullet 365}{55.65} \right]$$

Equation 10.21

where
EF = emission factor, kg $CH_4$/head/year
GE = gross energy intake, MJ /head/day
$Y_m$ = methane conversion factor (MCF), per cent of gross energy in feed converted to methane
The number of days of animal alive per annum (NAPA) is 365
The factor 55.65 (MJ/kg $CH_4$) is the energy content of methane

Methane EF for cattle enteric fermentation emission has been devised based on the $CH_4$ emission per animal per 365 d (kg $CH_4$/animal/year x *n*/365 days) (IPCC, 2006)), where *n* is the number of days an animal is estimated to live in a year (NAPA)), which in this case, 365 for mature cattle. Methane conversion factor ($Y_m$) is assumed at 6.5% for cattle that are fed low quality crop by-products and/or grazing condition. We assumed that similar practice for local cattle, which is mainly the integration under oil palm plantation comparable to grazing condition, thus value reported in IPCC guidelines (IPPC, 2006) was used for the calculation.

Gross energy (GE) is derived from sum of net energy requirements and the energy availability characteristics of the feed(s). The calculation was done as per Equation 10.16 of IPCC guidelines (IPCC, 2006) as follows:

Gross energy for cattle/buffalo and sheep

$$GE = \left[ \frac{\left( \frac{NE_m + NE_a + NE_l + NE_{work} + NE_p}{REM} \right) + \left( \frac{NE_g + NE_{wool}}{REG} \right)}{\frac{DE\%}{100}} \right]$$

Equation 10.16

where
GE = Gross energy, MJ/day
$NE_m$ = net energy required by the animal for maintenance (Equation 10.3), MJ/day
$NE_a$ = net energy for animal activity (Equation 10.4), MJ/day
$NE_l$ = net energy for lactation (Equation 10.8), MJ/day
$NE_{work}$ = net energy for work (Equation 10.11), MJ/day
$NE_p$ = net energy required for pregnancy (Equation 10.13), MJ/day
REM = ratio of net energy available in a diet for maintenance to digestible energy consumed (Equation 10.14)
$NE_g$ = net energy needed for growth (Equation 10.16), MJ/day

$NE_{wool}$ = net energy required to produce a year of wool, MJ/day (however, this value is not used since it is designated only for calculation associated with sheep)
REG = ration of net energy available for growth in a diet to digestible energy consumed (Equation 10.15)
DE% = digestible energy expressed as a percentage of gross energy

Net energy for maintenance ($NE_m$) is derived from calculation using Equation 10.3 of IPCC guidelines (IPCC, 2006), which refers to the amount of energy needed to keep the animal in equilibrium where body energy is neither gained nor lost (Jurgen, 1988). The equation is as follows:

Net energy for maintenance

$$NE_m = Cf_i \cdot (Weight)^{0.75}$$

Equation 10.3

where
$NE_m$ = net energy required by the animal for maintenance, MJ/day
$Cf_i$ = a coefficient which varies for each animal category as shown in Table 1.0 (Coefficients for calculating $NE_m$), MJ/day/kg as per table 10.4 in IPCC (2006) guidelines, Chapter 10.
Weight = live-weight of animal, kg

Net energy for activity ($NE_a$) was derived from Equation 10.4 of IPCC guidelines (2006), which refers to the energy needed by the animals in order for them to acquire food, water and shelter. The value is based on the feeding situation rather than the feed characteristics. The equation is as follows:

Net energy for activity

$$NE_a = C_a \cdot NE_m$$

Equation 10.4

where
$NE_a$ = net energy for animal activity, MJ/day
$C_a$ = coefficient corresponding to animal's feeding situation (IPCC, 2006).

Net energy for lactation ($NE_l$) was derived from Equation 10.8 of IPCC guidelines (IPCC 2006), which for cattle, expressed as a function of the amount of milk produced and its fat content expressed as a percentage, which in this case is 4% based on NRC (1989). The equation is as follows:

Net energy for lactation

$$NE_l = Milk \cdot (1.47 + 0.40 \cdot Fat)$$

Equation 10.8

where
$NE_l$ = net energy for lactation, MJ/day
Milk = amount of milk produced, kg of milk/day
Fat = fat content of milk, % by weight

Net energy for work ($NE_{work}$) is derived from calculation using Equation 10.11 of IPCC guidelines (2006), which is used to estimate the energy required for draft power. The energy intake requirements for various tasks with different strenuousness which influenced the energy requirements has been summarized by Bamualim and Kartiaso (1985), Ibrahim (1985) and Lawrence (1985). Ten percent of a day's $NE_m$ are required per hour for typical draft power requirements for each animal. The equation is as follows:

Net energy for work

$$NE_{work} = 0.10 \cdot NE_m \cdot hours$$

Equation 10.11

where
$NE_{work}$ = Net energy for work, MJ/day
$NE_m$ = Net energy required for animal maintenance per day (based on equation 10.3), MJ/day
Hours = Number of working hours per day

Net energy for pregnancy ($NE_p$) is derived from calculation using equation 10.13, which refers to the energy required for pregnancy. The total energy requirement for pregnancy for a 281-day gestation period averaged over an entire year is calculated as 10% of $NE_m$ (NRC, 1996; IPCC, 2006). When using $NE_p$ to calculate GE for cattle and sheep, the $NE_p$ estimate must be weighted by the portion of the mature females that actually go through gestation in a year. For example, if 80% of the mature females in the animal category give birth in a year, then 80% of the $NE_p$ value would be used in the GE equation as described earlier as per equation 10.16 of IPCC guidelines (2006). The equation for calculating the $NE_p$ value was as follows:

Net energy for pregnancy

$$NE_p = C_{pregnancy} \, . \, NE_m$$

Equation 10.13

where
$NE_p$ = Net energy for pregnancy, MJ/day
$C_{pregnancy}$ = co-efficient for pregnancy (for cattle, the co-efficient is 0.1 as described in NRC (1996) and IPCC 2006 Guidelines, chapter 10)
$NE_m$ = Net energy for maintenance, MJ/day (as derived from calculation using equation 10.3)

Ratio of net energy available in diet for maintenance to digestible energy consumed (REM) was estimated using equation 10.14 of IPCC guidelines (2006) as described by Gibbs and Johnson (1993). The equation is as follows:

Ratio of net energy available in a diet for maintenance to digestible energy consumed

$$REM = \left[1.123 - \left(4.092 \bullet 10^{-3} \bullet DE\%\right) + \left[1.126 \bullet 10^{-5} \bullet \left(DE\%\right)^2\right] - \left(\frac{25.4}{DE\%}\right)\right]$$

Equation 10.14

where
REM = ratio of net energy available in a diet for maintenance to digestible energy consumed
DE% = digestible energy expressed as a percentage of gross energy

Ratio of net energy available for growth in a diet to digestible energy consumed (REG) was estimated using equation 10.15 of IPCC guidelines (2006) as described by Gibbs and Johnson (1993). The equation is as follows:

Ratio of net energy available for growth in a diet to digestible energy consumed

$$REG = \left[1.164 - \left(5.160 \bullet 10^{-3} \bullet DE\%\right) + \left[1.308 \bullet 10^{-5} \bullet \left(DE\%\right)^2\right] - \left(\frac{37.4}{DE\%}\right)\right]$$

Equation 10.15

where
REG = ratio of net energy available for growth in a diet to digestible energy consumed
DE% = digestible energy expressed as a percentage of gross energy

Net energy for growth ($NE_g$) is derived from calculation using equation 10.6 of IPCC guidelines (2006) which is based on NRC (1996) for cattle of buffalo. Net energy for growth refers to the net energy needed by an animal for its growth associated activities such as weight gain. Constants for conversion from calories to joules and live to shrunk and empty body weight have been incorporated into the equation. The equation is as follows:

Net energy for growth (for cattle and buffalo)

$$NE_g = 22.02 \bullet \left(\frac{BW}{C \bullet MW}\right)^{0.75} \bullet WG^{1.097}$$

Equation 10.6

where
$NE_g$= net energy needed for growth, MJ/day
BW = the average live body weight (BW) of the animals in the population, kg
C = a coefficient with a value of 0.8 for females, 1.0 for castrates and 1.2 for bulls (NRC, 1996)
MW = the mature live body weight of an adult female in moderate body condition, kg
WG = the average daily weight gain of the animals in the population, kg/day

The country specific emission factor for methane emission from mature beef cattle enteric fermentation was devised using intake and production data from local Brakmas cattle, one of the main local beef breeds as this breed has been suggested to local farmers to help in increasing production and subsequently may help to increase the country's SSL as well, as partially fulfilling the aspiration of the National Agrofood Policy. Specific average production parameters from Brakmas cattle such as body weight (Johari, 2005; Mohd Hafiz *et al.*, 2010), number of days breeding cows were in milk, milk yield and milk fat content (Mohd Hafiz *et al.*, 2010; Syrstad, 1993), were used in the calculation. Other values such as % of DE was derived from Ulyatt *et al.* (2000), while default values such as pregnancy from IPCC guidelines (2006) were used when no country specific parameters were available. For daily weight gain, 0 kg/d value was used with the assumption that mature cattle are no longer gaining weight or included in growing activities in that particular stage. These parameters were then used as inputs for calculation using IPCC 2006 Tier-2 methodology equations as explained earlier to generate associated feed intake parameters and to finally calculate country specific emission factors (EF) for a particular livestock type aggregation (breeding/mature cow and breeding/mature bull). The values used and generated are summarized in Table 1.

Table 1: Average daily feed intake and production parameters used for developing local EFs for mature beef cattle (cow and bull) and Nett Energy (NE) values generated for various activities calculated using IPCC 2006 methodology

| Parameter | Breeding cow | Breeding bull |
|---|---|---|
| Digestible energy, DE (%) | 60.00 | 60.00 |
| Body weight (kg) (assuming birth weight 25 kg) | 350 | 500 |
| Number of days breeding cows are in milk | 90.0 | 0.0 |
| Milk yield (kg/d) | 3.0 | 0.0 |
| Milk fat content (%) | 4.0 | 0.0 |
| Pregnancy rate (%) | 80 | 0 |
| Days animal was alive in a year | 365 | 365 |
| Weight gain (kg/d) | 0.00 | 0.00 |
| Ratio of NE:DE for maintenance, REM | 0.49 | 0.49 |
| Ratio of NE:DE for growth, REG | 0.28 | 0.28 |
| NE maintenance (MJ/d/kg)(% of total GE requirement) | 27 (76) | 39 (85) |
| NE activity (MJ/day/kg) (% of total GE requirement) | 4.6 (13) | 6.7 (15) |
| NE lactation (MJ/day/kg) (% of total GE requirement) | 1.7 (5) | 0.0 (0) |
| NE pregnancy (MJ/day/kg) (% of total GE requirement) | 2.2 (6) | 0.0 (0) |
| Gross energy, GE (MJ/d) | 121 | 154 |
| Inferred GE from Tier 1 EF and 6.5% methane yield ($Y_m$) | 110 | 110 |
| Emission (kg $CH_4$ /animal/y) (365-d base) | 51.6 | 65.7 |
| Total enteric emission (kg $CH_4$/animal/y), EF | 51.6 | 65.7 |

*Uncertainty values of generated EFs*

Generating emission factors carries certain levels of uncertainty. Some possible sources of uncertainties in the inventory are the use of default values from IPCC as well as non-local animal production values in the calculations. However, because most of the values used originally did not report any uncertainty ranges, experts' judgment were used to assign the uncertainty ranges of the generated EF based on the sources of data in a consistent and transparent manner. The uncertainty range values for the EF generated are summarized in Table 2.

Table 2: Upper and lower uncertainty range value for the generated emission factor derived from experts' judgement

| Animal type | Gas | EF value (kg CH4/animal/y) | EF Uncertainty range (%) | | EF Uncertainty (%) |
|---|---|---|---|---|---|
| | | | -(lower) | + (upper) | |
| Mature cow | $CH_4$ | 51.6 | 30 | 30 | 30 |
| Mature bull | $CH_4$ | 65.7 | 30 | 30 | 30 |

## Results and Discussion

*Country-specific Emission Factors for mature beef cattle*

The local EFs developed for breeding cow and breeding bull were 51.6 and 65.7 kg $CH_4$/animal/y, respectively, (Table 2) which were higher than the default IPCC value of 47 kg $CH_4$/animal/y for a similar region. This was possibly due to the higher local average temperature where animals in nearby equatorial region have considerably higher emission compared to the default EF developed by IPCC in which considerations may include animal data from sub-temperate or sub-tropical highland climatic regions with lower emission, averaging in lower emission overall.

In addition, the default IPCC EF value is lower than the newly developed local EF probably due to the usage of average EF values of the mature cattle together with other age categories for beef cattle, such as birth to 1 year old and yearlings which understandably has much lower EF than the mature cattle itself.

*Uncertainty values for generated EF*

The uncertainty percentage range values were derived from expert judgement through discussions and workshops held with the Department of Veterinary Services in 2016. Both EFs (mature cow and mature bull) uncertainty ranges were suggested to be at ±30% and EF uncertainty at 30%. This meant that experts only believed that the EF generated was 70% acceptable to represent the local situation.

For the development of GHG inventory report using IPCC Tier-1 methodology, average value of both EF, which was 58.65 kg $CH_4$/animal/y and is suggested for use in the calculation of EF uncertainty ranges. The usage of average EF values for mature beef cattle to represent the total beef cattle (non-dairy) population $CH_4$ from enteric fermentation's EF was based on the assumption that average annual population number of cattle reported in DVS livestock statistics would mostly represent mature cattle. In addition, the usage of Tier-1 methodology does not require any livestock type and/or age aggregation to determine emissions from each age category.

The use of this newly developed local EF combined with IPCC Tier-1 methodology to enumerate total emission from livestock, gave a difference of up to 24.8% higher emission values than when using default IPCC EF of 47 kg $CH_4$/animal/d for beef cattle (non-dairy) $CH_4$ enteric emission. When using together with IPCC Tier-2 methodology to calculate total emission, individual EF for each age category may be used to get more accurate emission result.

## Conclusion

The developed EFs are suggested for use in the current national greenhouse gas inventory reporting to the UNFCCC in exchange of using the default IPCC Tier-1 EF. The use of these newly developed EFs would also offer better emission results which could represent the local situation than using the default IPCC EF. However, further extensive surveys and more structured analyses on livestock feed intake and production data are proposed to be conducted to refine the daily feed intake and production parameters to generate better estimates of EFs with lower uncertainty range values.

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## References

Bamualim, A. and Kartiarso. 1985. Nutrition of draught animals with special reference to Indonesia. In: Draught Animal Power for Production. J.W. Copland (ed). Australian Centre for International agricultural Research (ACIAR), Proceedings Series No. 10. ACIAR, Canberra, A.C.T., Australia.

Boland, M.J., Rae, A.N., Vereijken, J.M., Meuwissen, M.P.M., Fischer, A.R.H., Van Boekel, M. A.J.S., Rutherfurd, S.M., Gruppen, H., Moughan, P.J. and Hendriks, W.H. 2013. The future supply of animal-derived protein for human consumption. *Trends Food Sci. Technology*. 29: 62-73.

Devendra, C. 2007. Perspectives on animal production systems in Asia. *Livest. Sci.* 106: 1-18.

FAO. 2007. *FAOSTAT database*. Food and Agriculture Organization of the United Nations http://faostat.fao.org/. Retrieved 2 October 2017.

Gibbs, M.J. and Johnson, D.E. 1993. Livestock Emissions. In: International Methane Emissions, US Environmental Protection Agency, Climate Change Division, Washington, D.C., U.S.A.

Ibrahim, M.N.M. 1985. Nutritional status of draught animals in Sri Lanka. In: Draught Animal Power for Production, J.W. Copland (ed). ACIAR (Australian Centre for International Agricultural Research) Proceedings Series No. 10. ACIAR, Canberra, A.C.T., Australia.

IPCC. 2007. Climate change: The Physical Science Basis. IPCC Fourth Assessment Report (AR4). 2007. Available online: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html

IPCC. 2014. Climate Change 2014 Synthesis Report Summary for Policymakers. Assesment report 5 (AR5). Available online: https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf

IPCC. 2006. Guidelines for National Green House Gas Inventories. Agriculture, Forestry and Land Use (AFOLU) Chapter 10. Vol 4.

IPCC. 1997. IPCC Guidelines for National Greenhouse Gas Inventories, 1st Edition., IPCC WGI Technical Suppport Unit, Paris, ISBN-10: 9264155783, pp. 950.

Johari, J.A. 2005. Manual Teknologi Penggandaan Lembu Brakmas di Ladang Kelapa Sawit. Penerbit MARDI.

Johnson K.A. and Johnson D.E. 1995. Methane emissions from cattle. *J. Anim. Sci*. 73: 2483-2492.

Jurgen, M.H. 1988. Animal Feeding and Nutrition, 6th Edition, Kendall-Hunt Publishing Company, Dubuque, Iowa, U.S.A.

Kandel, P.B., Gengler, N. and Soyeurt, H. 2015. Assessing variability of literature based methane indicator traits in a large dairy cow population. *Biotechnol. Agron. Soc. Environ*. 19(1): 11-19.

Lassey, K. R. 2007. Livestock methane emission: from the individual grazing animal through national inventories to the global methane cycle. *Agric. For. Meteorol.* 142: 120-132.

Lawrence, P.R. 1985. A review of nutrient requirements of draught oxen. In: Draught Animal Power for Production. J.W. Copland (ed). ACIAR (Australian Centre for International Agricultural Research) Proceedings Series No. 10. ACIAR, Canberra, A.C.T., Australia.

Ministry of Natural Resources and The Environment Malaysia (NRE) 2015. Biennial Update Report (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC) 2011.

MOA. 2011. Dasar Agromakanan Negara 2011-2020. pp. 138.

Mohd Hafiz, A.W., Ariff, M.O., Nik Muhammad Salmi Adli, S. and Johari, J.A. 2010. Reproductive performance of Brakmas cattle under open pasture management system. Proc. of 31st MSAP Ann. Conf. pp 147-148.

National Research Council (NRC) (1989). Nutrient Requirements of Dairy Cattle, 6$^{th}$ Ed., Nat. Acad. Press, Washington, DC.

National Research Council (NRC) (1996). Nutrient Requirements of Beef Cattle, 7$^{th}$ Ed., Nat. Acad. Press, Washington, DC.

Ranjeeta, P. 2013. Malaysia keeps palm oil export tax unchanged to spur shipments. Bloomberg News. https://www.bloomberg.com/news/articles/2013-09-17/malaysia-keeps-palm-oil-export-tax-unchanged-to-spur-shipments. Retrieved 10 October 2017

Schwarzer, S., Witt, R. and Zommers, Z. 2012. Growing greenhouse gas emissions due to meat production. UNEP Global Environmental Alert Services (GEAS).

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. and De-Haan, C. 2006. Livestock's long shadow: environmental issues and options: FAO Rome.

Syrstad, O. 1993. Evaluation of dual-purpose (milk and meat) animals. *World Animal Review* 77: 56-59.

Ulyatt, M.J., Lassey, K.R., Johnson, D., Gibbs, M.J. and Coneely, D. 2000. $CH_4$ Emissions from enteric fermentation: IPCC Good Practice Guidance and Uncertainty Management in National Green House Gas Inventories. pp 297-320.