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A Response of Feed Utilization and Greenhouse Gas Emissive Intensity of Cattle to Dietary Concentrate-To-Forage Ratio in Southwestern Vietnam

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Abstract

An experiment was conducted on 12 male crossbred (Red Sindhi x local, *Bos indicus*) cattle from 104 to 165 kg of live weight to evaluate the influence of the dietary concentrate-to-forage (C:F) ratio from 1:10, 1:6, 1:4 to 1:3 on their feed intake, Weight Gain (WG), Feed Conversion Ratio (FCR), digestible nutrients and Greenhouse Gas (GHG) emission. A completely randomized block design was used and all data were submitted to analysis of variance and to compare of treatment pairs by Tukey's test. The animals were fed *ad libitum* with forage of rice straw combined/no elephant grass and different commercial concentrate level in individual houses for 90 days. The results found that the feed intake, WG, and GHG emission linearly increased with the C:F ratio ranging from 1:10, 1:6, 1:4 to 1:3 while the *in vivo* Digestible Neutral Detergent Fiber (DNDF) and acid detergent fiber were decreased ($P < 0.01$). There were no effects ($P > 0.05$) of the dietary C:F ratio on the *in vivo* digestible organic matter, digestible crude protein and total digestible nutrients. The *in vitro* DNDF ($P < 0.05$) Using Rumen Fluid of Slaughtered Cattle (RFSC) without reagents for the medium was the same *in vivo* trend ($R^2 = 0.97$, RSD = 0.59). The WG/GHG emission was significantly increased ($P < 0.01$) up to the C:F ratio of 1:4, but at the C:F ratio of 1:3 slightly had a decreasing trend. It, therefore, was concluded that the dietary C:F ratio of 1:4 was more efficient in fiber utilization and GHG emissive intensity. The *in vitro* technique using RFSC unknown dietary history without reagents for medium had the potential to be used for predicting the dietary fiber utilization of cattle.

Introduction

The Greenhouse Gases (GHG) consisting of carbon dioxide, methane, and nitrous oxide emitted from the livestock sector is a partly important cause of global warming which is about 6.3% globally [1]. Vietnamese census data suggest one of the hardest challenges ensuring climate change regulatory must be to reduce 6.30 million metric tons of carbon dioxide equivalents GHG from the livestock sector [2] and a significant proportion comes from ruminants, accounting for 34.6% [3]. Currently, the GHG inventory from cattle in Vietnam is according to IPCC (2006) Tier 2. Tier 2 relies on the conversion factor of 6.5±1.0% gross energy intake while which is extremely variable with dietary concentrate level, fiber, and energy [4]. Southwestern Vietnam, also known as Mekong Delta (MD) with the area of 40,577 km^2 of which ~ 26 thousand km^2 is used for agriculture, but the pasture area is limited. Feeds for cattle in the region are a low quality which is mainly rice straw. Fortunately, the forages feeding cattle are also abundantly in nature or farming, but low quality. The cattle herd in the MD is about 711,915 heads in 2016 accounting circa 13.0% of the national herd and is mainly used for beef (95.5%). The national planning is to increase the cattle population up to ~ 6.3 million heads and the MD will reach up to ~ 822.5 thousand heads in 2020 [5] for partly meeting the red meat demand of the population in the region ~ 18 million people. The most popular breed of beef cattle in the MD is crossbred between local female and Red Sindhi male, which Vietnamese often call Lai Sind cattle nominally belonging to *Bos indicus* with the relative frequency of 90.2% [6], because they are adaptive to hot-humid climate of the delta and bigger body than local cattle, but their growth rate is low yet. Therefore, it should be considered to apply intensive farming to cattle in the MD by elevating the concentrate level reasonably to improve growth rate, to shorten feeding period, and hence the GHG issues will be reduced [7]. However, the concentrate-to-forage (C:F) ratio in diets affects digestible nutrients and enteric GHG emission in many ruminants [8-12] but have not yet been investigated in the MD, Vietnam.

Digestible fiber for ruminants is an important criterion for evaluating the energy utilization from the plant for protein production. Dietary fibers are able to be fermented by rumen microorganisms to supply an energy source for host cattle while humans cannot digest. The most accurate way of obtaining dietary digestible fiber for cattle is that conducting an *in vivo* experiment. It is considered to be a standard procedure. However, the *in vivo* technique has been criticized due to the laborious and expensive to carry out. Numerous attempts have been developing simple techniques for determining dietary digestible nutrients for cattle. The two-stage *in vitro* technique of Tilley and Terry [13]

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modified by Goering and Van Soest [14] is one of such techniques. The *in vitro* technique relies on the rumen fluid for inoculums and some reagents for medium. This practice has challenges due to issues of moral related to maintaining fistulated animals and environment related to using some reagents for medium. Some attempts have been made to search for inoculum from slaughtered animals [15,16]. Moreover, rumen fluid has been known as a perfect environment for microbial fermentation due to containing high ammonium, peptides, amino acids, volatile fatty acids, minerals, vitamins, other co-factors, and could be used to replace medium for the *in vitro* digestion [15,17]. A goal question for this study: to what concentrate level we can feed cattle not only gain better growth rate to shorten feeding period and mitigate GHG emission intensity, but also have efficiencies for economic and fiber utilization; and the *in vitro* technique limited reagents could evaluate this digestible fiber.

Materials and Methods

Animals and feeds

There were 12 male crossbred (Red Sindhi x local) cattle with the live weight from 104 to 165 kg in an experiment located at 9°40'59.5"N and 105°54'58.7"E. They were wiped out parasites with Invermectin 0.25% before used for the experiment. The forage feeding cattle was rice straw plus/no elephant grass (Table 1). The grass was cut daily from the field near the farm after cultivating or regenerating from 45 to 60 days of age. Rice straw was once collected during the experiment from fields near the experimental site in a winter-spring season with a variety of OM7347. The concentrate feeding cattle was a commercial product purchased once during the experimental period from a feed shop.

Experimental design and feeding

The experiment was designed as a completely randomized block consisting of four treatments and three blocks. The treatments were the dietary concentrate-to-forage (C:F) ratio of 1:10, 1:6, 1:4 and 1:3 (dry matter, DM basis). The experimental diets contained crude protein (CP, 9.01 – 9.06% DM) and metabolizable energy (ME, 2042 - 2054 kcal/kg DM) content equivalently. The blocks were different initial live weight groups (104 - 107, 130 - 134 and 160 - 165 kg). Each cattle grew up in an individual house with 3 x 1.5 m to be considered as a unit. The houses are appended feeder and drinking through separately and disinfected monthly by Virkon'S. The cattle were fed *ad-libitum* with concentrate at 8:00 am and at 5:00 pm and then the forage. Water was supplied free access during all experimental time. The experimental period was 90 days. The ingredients and chemical composition of diets are shown in Table 1.

Measurements, sampling, and chemical analysis

The voluntary feed intake was recorded as differences of the offered feeds in the morning and the refusals in the next morning. Furthermore, the animals were individually weighed twice at the initial and final experiment period to observe live weight change. The feeds, refusals, and feces were weighed and sampled each morning for 7 consecutively middle days of the experiment to determine *in vivo* digestible nutrients. After collection, all samples were dried at 55 °C for 24 hours to grind fine through a sieve with size 1 mm, pooled and stored at -20 °C for waiting for chemical analysis and the *in vitro* fermentation [14].

The DM was determined by drying at 105 °C for 12 hours. The Organic Matter (OM) and ash were furnacing at 550 °C for 3 hours. The CP was analyzed by the micro-Kjeldahl method and the ether extract was analyzed by keeping the sample in ethyl ether to extract in a Soxhlet system [18]. Determinations of Neutral Detergent Fiber (NDF), acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) was according to Goering and Van Soest [14].

In vitro digestion

The rumen liquor source for *in vitro* digestion was freshly removed from three slaughtered crossbred (Red Sindhi x local) cattle unknown dietary history. About 15 minutes post-slaughter, the rumen of each animal was cut open with a kitchen knife to collect the contents which were immediately strained into pre-warmed thermal flasks through three layers of a muslin cloth at each occasion, pooled one, and transported back to the laboratory quickly. The *in vitro* procedure for the digestible OM (DOM) and NDF (DNDF) determination was proposed by The procedure was similar to the proposal of Goering and van Soest [14] but it only used 42 ml rumen fluid, 8 ml buffer and 2 ml reducing, without medium for microbes to ferment substrate. The buffer and reducing solution were prepared according to Goering and van Soest [14]. After fermentation 72 hours in glass tubes at 39 °C, the substrate residue was treated with the neutral detergent solution at 85 °C overnight, washed twice with hot water and twice with acetone; then dried, weighed and waited for OM and NDF analysis. Blanks consisting of rumen fluid and buffer without substrate were included for correcting the result due to rumen fluid residual particle.

Data calculation and statistical analysis

According to McDonald Non-Fiber Carbohydrate (NFC) was estimated as (OM – CP – EE – NDF), hemicellulose was estimated as (NDF – ADF), and cellulose was estimated as (ADF – ADL). The Metabolizable Energy (ME) value of ingredients was calculated following models of Detmann et al., [19]. The Total Digestible Nutrients (TDN) was calculated from the *in vivo* digestible nutrients

Table 1: The ingredients and chemical composition of diets in the experiment.

Composition, % DM	Dietary concentrate-to-forage ratio			
	1:10	1:6	1:4	1:3
Rice straw	14.4	34.9	48.8	66.4
Grass	77.8	47.1	25.9	0.0
Concentrate	7.82	18.0	25.3	33.6
Dry matter	15.8	23.3	34.9	85.6
Organic matter	88.3	87.6	87.1	86.5
Crude protein	9.05	9.04	9.06	9.01
Ether extract	2.47	3.02	3.42	3.85
Non-fiber carbohydrate	7.43	8.69	9.59	10.6
Neutral detergent fiber	69.3	66.8	65.0	63.0
Acid detergent fiber	36.4	35.6	35.1	34.5
Acid detergent lignin	5.99	6.15	6.26	6.41
Hemicellulose	33.0	31.2	30.0	28.5
Cellulose	30.4	29.5	28.8	28.1
Metabolizable energy, kcal/kgDM	2042	2054	2025	2040

Table 2: Effects of the dietary C:F ratio on nutrients and energy consumption of cattle.

Variables	Dietary concentrate-to-forage ratio				SEM	P-value
	1:10	1:6	1:4	1:3		
Dry matter, kg/day	2.76[b]	2.92[b]	3.38[b]	4.39[a]	0.264	***
Organic matter, kg/day	2.44[b]	2.56[b]	2.94[b]	3.80[a]	0.224	***
Crude protein, g/day	251[b]	264[b]	305[b]	395[a]	20.0	***
Ether extract, g/day	68.4[c]	88.3[bc]	115[b]	169[a]	9.94	***
Non-fiber carbohydrate, g/day	205[c]	254[bc]	324[b]	466[a]	29.4	***
Neutral detergent fiber, kg/day	1.92[b]	1.95[b]	2.20[b]	2.77[a]	0.167	**
Acid detergent fiber, kg/day	1.01[b]	1.04[b]	1.19[b]	1.52[a]	0.094	**
Hemicellulose, kg/day	0.913[b]	0.912[b]	1.01[b]	1.25[a]	0.073	**
Cellulose, kg/day	0.840[b]	0.861[b]	0.975[b]	1.24[a]	0.076	**
Acid detergent lignin, g/day	165[b]	180[b]	212[b]	282[a]	18.8	***
Metabolizable energy intake, Mcal/day	5.66[b]	6.01[b]	6.85[b]	8.95[a]	0.505	***

SEM – Standard Error of Mean; P-value: ** – $P < 0.01$; *** – $P < 0.001$; [a–c] – means with different superscripts are significantly different according to Tukey's test.

[20]. The enteric methane emission was calculated following the model of Yan et al., [4]. The fecal methane and nitrous oxide emissions were calculated following the models of IPCC [1]. The dioxide carbon emissions were not estimated as a recommendation of IPCC (2006). The *in vitro* DOM and DNDF were estimated as [((OM of feed taken for incubation – (OM residue + blank)) × 100)/DM of feed taken for incubation] and [((NDF of feed taken for incubation – (NDF residue + blank)) × 100)/DM of feed taken for incubation].

All data were submitted to analysis of variance by using the command of Stat>ANOVA>General Linear Model in Minitab 17 Statistical Software, and Tukey's test was also used to compare treatment pairs.

Results and Discussions

Nutrients consumption

The consuming data of nutrients and ME were presented in Table 2.

Table 2 shows the consumption of nutrients (e.g., DM, OM, CP, EE, NFC, NDF, ADF, ADL, hemicellulose and cellulose) and ME increased linearly with the dietary C:F ratio ranging from 1:10, 1:6, 1:4 to 1:3 with significant levels $P < 0.01$. It is possible that the feed intake was influenced through increasing the concentrate level, reducing the level of fiber in the diets and increasing the passage rate, thereby decreasing retention in the rumen, resulting in a linear increase in intake [21]. Several papers have discussed the effect of incorporating concentrate into diets with respect to producing changes in the digestive process and metabolism of nutrients [21-23]. Similarly, Ba et al., [24] found the organic matter intake of Yellow Cattle in Central Vietnam fed elephant grass and rice straw increased linearly from 2.28 to 3.91 kg/day as the amount of concentrate consumption increased from zero to 2.45 kg DM/day. Dung et al., [22] recorded Vietnamese local cattle consumed feed linearly with concentrate intake from 1.0, 1.4, and 1.8 to 2.2 % of live weight. Quang et al., [23] observed the total feed intake of Brahman crossbred cattle in Southeastern Vietnam fed Guinea grass and rice straw increased from 4.02 to 6.43 kg DM/day as the quantity of concentrate intake increased from 0 to 4.29 kg DM/day.

Table 3: Effects of the dietary C:F ratio on *in vivo* and *in vitro* digestible nutrients.

Variables, % DM	Dietary concentrate-to-forage ratio				SEM	P-value
	1:10	1:6	1:4	1:3		
In vivo						
Digestible organic matter	52.9	52.5	52.3	52.6	0.613	ns
Digestible crude protein	5.55	5.53	5.61	5.56	0.252	ns
Digestible ether extract	1.47[d]	2.02[c]	2.42[b]	2.85[a]	0.047	***
Digestible non-fiber carbohydrate	7.28[d]	8.52[c]	9.40[b]	10.4[a]	0.051	***
Digestible neutral detergent fiber	46.8[a]	44.7[b]	42.2[c]	40.5[d]	0.423	***
Digestible acid detergent fiber	19.8[a]	18.9[a]	17.5[ab]	15.6[b]	0.919	**
Total digestible nutrients	55.9	56.2	55.6	55.9	0.624	ns
In vitro						
Digestible organic matter	54.2	54.1	53.3	52.8	0.634	ns
Digestible neutral detergent fiber	36.9[a]	35.2[ab]	32.9[ab]	31.4[b]	0.454	*

SEM – standard error of mean; P-value: * – $P < 0.05$; *– $P < 0.01$; *** – $P < 0.001$; ns – non significant; [a-d] – means with different superscripts are significantly different according to Tukey's test

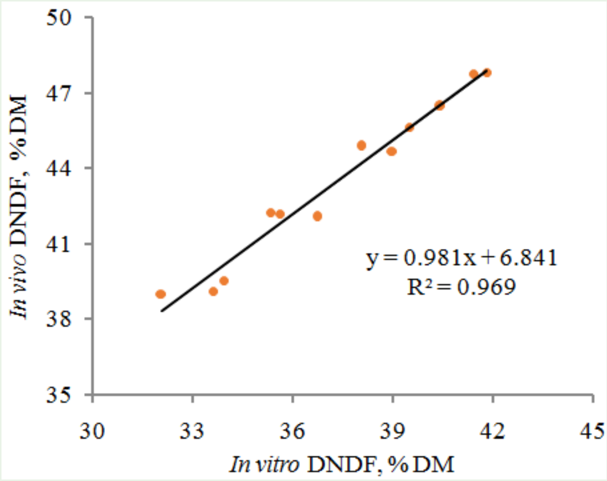

Figure 1: A relationship between *in vivo* and *in vitro* digestible neutral detergent fiber.

Nutrients utilization

The dietary digestible nutrients of experimental cattle determined by the *in vivo* and *in vitro* techniques (Table 3) shows that the DOM, DCP, and TDN of cattle were not significantly different among treatments ($P > 0.05$). The DNFC and DEE increased linearly ($P < 0.01$) as the C:F ratio increased. However, there were significant ($P < 0.01$) decreases in the *in vivo* DNDF and DADF as the C:F ratio increased. The highest DADF value was in the C:F ratio of 1:10 but not significantly ($P > 0.05$) different from the C:F ratio of 1:4. Similarly, the *in vitro* DNDF were found a decreasing trend ($P < 0.05$) as the dietary C:F ratio increased.

An decrease in the C:F ratio increased the DOM for other ruminants, such as a cow [25], Buffalo [12], sheep [26] and goat because the forage has a generally higher NDF content than the concentrate. As structural carbohydrates (e.g. NDF) are usually less digestible than non-fiber carbohydrates, the total digestibility decreases with increasing proportions of forage in the diet. However, there were no effects on DOM and TDN in the present study, probably due to the same ME setting for all treatments. In agreement with previously reported results in other studies on steer [27] and Buffalo [12] in the present study, the DNDF and DADF decreased ($P < 0.01$) with increasing dietary C:F ratios as the ME content was set equivalent.

Figure 1 shows the *in vivo* DNDF (coefficient of determination – R^2 = 0.97, residual standard deviation – RSD = 0.59) had close relationships to the *in vitro* DNDF of using rumen fluid without reagents for medium. Thus rumen liquor of slaughtered cattle of unknown dietary history only plus a little of the buffer could be used to derive nutritionally important parameters of diets for cattle. This achievement is agreements with Lutakome et al., [28] that rumen liquor from slaughtered cattle of unknown dietary history can be used to derive the *in vitro* gas production parameters. Wang et al., [29] found that the *in vitro* test with rumen fluid from slaughtered cattle could use for capturing variation in methane emission potential between cattle types and with age. Denek et al., [30] stated that both slaughtered cow and sheep rumen fluid could use as inoculum for the *in vitro* digestion and got the R^2 value of 0.80 for predicting the *in vivo* DM digestibility. The successful introduction of rumen fluid of slaughtered animals without reagents for the *in vitro* digestion would promise in responding to challenges of ethical and environmental issues.

Performance and greenhouse gas emission

The variables relating to the performance, GHG emission, and economic efficiency were presented in Table 4.

Table 4 shows that the final live weight increased from 159 to 181 kg significantly ($P < 0.001$) as the dietary C:F ratio ranged from 1:10, 1:6, 1:4 to 1:3, hence the mean weight gain improved from 285 to 525 g/day significantly ($P < 0.001$). However, no differences ($P > 0.05$) were between the 1:10 and 1:6 treatments. The lowest figures were found for the variable of feed conversion ratio was in the 1:3 treatment but not significantly different ($P > 0.05$) from the 1:6 and 1:3 treatment. Feed cost/weight gain was the best in the 1:3 treatment, the highest in the 1:10 treatment, and significantly ($P < 0.001$) different among treatments.

Similarly, Nellore heifers fed with 45% concentrate had greater weight gain (0.90 kg) than that (0.74 kg) of those fed with 22.5% concentrate diet [31]. Quang et al., [23] showed that the average weight gain of Brahman crossbred cattle increased from 0.092 to

Table 4: Effects of the dietary C:F ratio on weight gain and greenhouse gas intensity.

Variables	Dietary concentrate-to-forage ratio				SEM	P-value
	1:10	1:6	1:4	1:3		
Final live weight, kg	159^c	162^{bc}	168^b	181^a	2.34	***
WG, g	285^c	311^c	393^b	525^a	19.7	***
FCR	9.72^a	9.40^{ab}	8.50^{ab}	8.32^b	0.536	*
Feed cost/WG, 1,000 VND/kg	69.9^a	59.3^b	48.4^c	41.0^d	1.68	***
Enteric GHG, kgCO_2 eq.	1.94^b	1.97^b	2.27^b	3.10^a	1.51	***
Manure GHG, kgCO_2 eq.	0.144	0.127	0.158	0.183	0.020	ns
Total GHG, kgCO_2 eq.	2.09^b	2.09^b	2.43^b	3.28^a	0.156	***
WG/GHG, g/kgCO_2 eq.	138^b	149^{ab}	165^a	161^a	6.18	**
Feed cost/WG/GHG, VND/g/kg	146^a	124^{ab}	119^b	135^{ab}	10.2	*

WG – Weight Gain, FCR – Feed Conversion Ratio, GHG – Greenhouse Gas; SEM – Standard Error Of Mean; P-value: * – $P < 0.05$; *– $P < 0.01$; *** – $P < 0.001$; ns – non significant; $^{a-c}$ – means with different superscripts are significantly different according to Tukey's test.

0.943 kg/day as supplementing concentrate from 0 up to 67%. This improvement is likely due to the increase in the feed intake resulting from an increase in the dietary C:F ratio, and consistent with previously published reports where supplements have been fed to provide energy and/or protein [32,33]. The feed efficiency increased linearly with increasing the concentrate level, which is consistent with Silva et al., [27] who reported that increased concentrate levels from 17% to 68% feeding crossbred dairy steers in Brazil improved the feed conversion ratio. However, Helal et al., [34] found that feed efficiency decreased and feed cost for weight gain increased with the increase in concentrate level (70 to 100%) for buffalo calves in Egypt. Rashid et al., [35] also recognized that Brahman crossbred calves in Bangladesh had lower feed efficiency and higher feed cost for gain with the increase in concentrate level from 55 to 75%.

Table 4 shows that the enteric methane and total GHG emission increased significantly ($P < 0.001$) as the dietary C:F ratio ranged from 1:10, 1:6, 1:4 to 1:3 while the manure GHG was not significantly ($P > 0.05$) different among treatments. The weight gain/GHG emission was significantly increased ($P < 0.01$) up to the dietary C:F ratio of 1:4, but at the dietary C:F ratio of 1:3 slightly had a decreasing trend. There was significantly ($P < 0.001$) different among treatments for feed cost/weight gain/GHG emission which was the lowest in the C:F ratio of 1:4, and the highest in the C:F ratio of 1:10. Na et al., [10] illustrated the enteric methane and carbon dioxide in goats and Sika deer (*Cervus nippon hortulorum*) decreased with the forage to concentrate ratio from 25:75, 50:50 to 73:27. The results are in line with Niu et al., [36] who reported lower methane emission from Holstein cow in the USA on reducing dietary forage. Similarly, the methane emission intensity from animals was also reduced as an increase in the concentrate level from 20 to 60% feeding buffaloes calves in India, from 17 to 68% feeding crossbred dairy steers in Brazil, from 2.0 to 8.0 kg/day feeding grazing dairy cows in the UK [37], and from 55 to 75% feeding Brahman crossbred calves in Bangladesh.

Actually, a major problem with traditional beef cattle conditions in the MD on low-quality forages results in low growth rate and long production periods, and thus high overall outputs of GHG. The reduction in GHG emission should arise from the fact that growth rate is better and thus feeding period to achieve slaughter weight is short. Thus cattle in the tropical region on low-quality forage should be fed with the high-concentrate level to grow faster and also finish faster with consequent of improvements in feed efficiency and less cost. The scenarios from Ngoan et al., [38] and Dung et al., [33] for beef cattle in Central Vietnam also indicated a reduction in GHG emission intensity by increasing the concentrate level-up to 37% and 45%, respectively but out of the experimental running. This experiment indicated that the dietary C:F ratio of 1:4 was suitable for improving weight gain and feed efficiency, mitigating GHG emission intensity, and lowing feed cost.

Conclusions

The feed intake, weight gain and GHG emission of crossbred cattle increased linearly with an increase in the dietary C:F ratio up to 1:3 while the DNDF and DADF were lowered; even so, the dietary C:F ratio of 1:4 was more efficient in gain performance, fiber utilization, and GHG emissive intensity. The rumen fluid of slaughtered cattle unknown dietary history without reagents for medium had the potential to be used for predicting the dietary DNDF.

References

1. IPCC - Intergovernmental Panel on Climate Change. IPCC guidelines for national greenhouse gas inventories: emissions from livestock and manure management. 2006; 10.1-10.84.
2. MARD - Ministry of Agriculture and Rural Development. Decision 3119/QD-BNN-KHCN, December 12, 2011, on approving the program on greenhouse gas emissions reduction in Agriculture and Rural Development sector up to 2020. Hanoi, Vietnam. 2011.
3. Hieu NK, Hai TD, Hoa HM, Phung BH, Yen PH. Update report two years the first of Vietnam for Union Convention on climate change, Ha Noi, Vietnam. 2014; 98.
4. Yan T, Porter MG, Mayne CS. Prediction of methane emission from beef cattle using data measured in indirect open-circuit respiration calorimeters. Animal. 2009; 3: 1455-1462.
5. MARD - Ministry of Agriculture and Rural Development. Decision 639/QD-BNN-KH, April 2nd, 2014, on approving the agricultural and rural planning in the Mekong Delta up to 2020 with a vision up to 2030 in the context of climate change. Hanoi, Vietnam. 2014.
6. GSO - General statistics office. Statistical yearbook of Vietnam 2016 (Vietnamese). Statistical Publishing House, Hanoi, Vietnam. 2017.
7. FAO - Food and Agriculture Organization of the United Nations. Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities, Rome, Italy. 2013.
8. Lovett D, Lovell S, Stack L, Callan J, Finlay M, Conolly J, O'Mara FP. Effect of forage/concentrate ratio and dietary coconut oil level on methane output and performance of finishing beef heifers. Livest. Prod. Sci. 2003; 84:135-146.
9. Aguerre MJ, Wattiaux MA, Powell JM, Broderick GA, Arndt C. Effect of forage-to-concentrate ratio in dairy cow diets on emission of methane, carbon dioxide, and ammonia, lactation performance, and manure excretion. J. Dairy Sci. 2011; 94: 3081-3093.
10. Na Y, Li DH, Lee SR. Effects of dietary forage-to-concentrate ratio on nutrient digestibility and enteric methane production in growing goats (Capra hircus hircus) and Sika deer (Cervus nippon hortulorum). Asian-Aust. J. Anim. Sci. 2017; 30: 967-972.
11. Patra A, Park T, Kim M., Yu Z. Rumen methanogens and mitigation of methane emission by anti-methanogenic compounds and substances, Journal of Animal Science and Biotechnology. 2017; 8: 13-31.
12. Nampoothiri VM, Mohini M, Malla BA, Mondal G, Pandita S. Growth performance, and enteric and manure greenhouse gas emissions from Murrah calves fed diets with different forage to concentrate ratios. Anim. Nut. 2018; 4: 215-221.
13. Tilley JMA, Terry RA. A two stage technique for the in vitro digestion of forage crops. Grass Forage Sci. 1963; 18: 104-111.
14. Goering HK, Van Soest PJ. Forage fiber analyses, Agricultural Handbook 379, USA. 1970; 20.
15. Mo D, Thu NV. Using buffalo rumen fluid as alternative nutrients with chemicals for microbes in *in vitro* digestibility measurement of ruminant feeds. Scientific Journal of Cantho University. 2008; 9: 151-160.
16. Mohamed RAI, Chaudhry dAS. Fresh or frozen rumen contents from slaughtered cattle to estimate in vitro degradation of two contrasting feeds. Czech J. Anim. Sci. 2012; 57: 265-273.
17. Mo D, Thu NV. A determination of pH value and concentration of some nutrients in rumen fluid of ruminant species. Journal of Animal Science and Technology. 2009; 18: 23-29.
18. AOAC. Official methods of analysis, 15th edition. Association of Official Analytical Chemist. Washington DC, USA. 1990.

19. Detmann E, Filho SCV, Pina DS, Henriques LT, Paulino MF, Magalhaes KA et al. Prediction of the energy value of cattle diets based on the chemical composition of the feeds under tropical conditions. Anim. Feed Sci. Technol. 2008; 143: 127–147.

20. NRC. Nutrient requirements of dairy cattle (7th revised edition). National Academy Press, Washington, D. C., USA. 2001.

21. Manni K, Rinne M, Huhtanen P. Comparison of concentrate feeding strategies for growing dairy bulls. Lives. Sci. 2013; 152: 21-30.

22. Dung DV, Ba NX, Van NH, Phung LD, Ngoan LD, Cuong VC, Yao W. Practice on improving fattening local cattle production in Vietnam by increasing crude protein level in concentrate and concentrate level. Trop. Anim. Health Prod. 2013; 45: 1619-1626.

23. Quang DV, Ba NX, Doyle PT, Hai DV, Lane PA, Malau-Aduli AEO et al. Effect of concentrate supplementation on nutrient digestibility and growth of Brahman crossbred cattle fed a basal diet of grass and rice straw. J. Anim. Sci. Technol. 2015; 57: 35.

24. Ba NX, Van NH, Ngoan LD, Leddin CM, Doyle PT. Effects of amount of concentrate supplement on forage intake, diet digestibility and live weight gain in yellow cattle in Vietnam. Asian-Aust. J. Anim. Sci. 2008; 21: 1736-1744.

25. Yang WZ, Beauchemin KA, Rode LM. Effects of grain processing, forage to concentrate ratio, and forage particle size on rumen pH and digestion by dairy cows. J. Dairy Sci. 2001; 84: 2203-2216.

26. Ramos S, Tejido ML, Martinez ME, Ranilla MJ, Carro MD. Microbial protein synthesis, ruminal digestion, microbial populations, and nitrogen balance in sheep fed diets varying in forage-to-concentrate ratio and type of forage. J. Anim Sci. 2009; 87: 2924-2934.

27. Silva GSd, Véras ASC, Ferreira MdA, Dutra WMJr, Neves MLMW, Souza EJO et al. Performance and carcass yield of crossbred dairy steers fed diets with different levels of concentrate. Trop. Anim. Health Prod. 2015; 47: 1307-1312.

28. Lutakome P, Kabi F, Tibayungwa F, Laswai GH, Kimambo A, Ebong C. Rumen liquor from slaughtered cattle as inoculum for feed evaluation. Anim. Nutr. 2017; 3: 300-308.

29. Wang S, Pisarčíková J, Kreuzer M, Schwarm A. Utility of an in vitro test with rumen fluid from slaughtered cattle for capturing variation in methane emission potential between cattle types and with age. Canadian J. Anim. Sci. 2018; 98: 61-72.

30. Denek N, Can A, Koncagül S. Usage of slaughtered animal rumen fluid for dry matter digestibility of ruminant feeds. J. Anim. Vet. Adv. 2006; 5: 459-461.

31. Gionbelli MP, Filho SDCV, Detmann E, Paulino PVR, Valadares RFD, Santos TR et al. Intake, performance, digestibility, microbial efficiency and carcass characteristics of growing Nellore heifers fed two concentrate levels. R. Bras. Zootec. 2012; 41: 1243-1252.

32. Contadini MdA, Ferreira FA, Corte RRS, Antonelo DS, Gómez JFM, Silva SdL. Roughage levels impact on performance and carcass traits of finishing Nellore cattle fed whole corn grain diets. Trop. Anim. Health Prod. 2017; 49: 1709-1713.

33. Dung D.V., L.D. Phung, L.D. Ngoan and T.D. Searchinger. Current status and scenarios for reducing methane emission from smallholders' semi-intensive beef cattle production system in Quang Ngai province. Vietnam J. Agri. Sci. 2016; 14: 699-706.

34. Helal FIS, Abdel-Rahman KM, Ahmed BM, Omar SS. Effect of feeding different levels of concentrates on buffalo calves performance, digestibility and carcass traits. Am-Euras. J. Agric. Environ. Sci. 2011; 10: 186-192.

35. Rashid MM, Huque KS, Hoque MA, Sarker NR, Bhuiyan AKFH. Effect of concentrate to roughage ratio on cost effective growth performance of Brahman crossbred calves. J. Agri. Sci. Technol. 2015; A5: 286-295.

36. Niu M, Appuhamy JADRN, Leytem AB, Dungan RS, Kebreab E. Effect of dietary crude protein and forage contents on enteric methane emissions and nitrogen excretion from dairy cows simultaneously. Anim. Prod. Sci. 2016; 56: 312-321.

37. Jiao HP, Dale AJ, Carson AF, Murray S, Gordon AW, Ferris CP. Effect of concentrate feed level on methane emissions from grazing dairy cows. J. Dairy Sci. 2014; 97: 7043-7053.

38. Ngoan LD, Dung DV, Searchinger TD, Phung LD. Current situation and scenarios for reducing enteric methane emission from extensive beef cattle production system of smallholders in Quang Ngai province, Vietnam. J. Sci. (Cantho university) 2016; 46b: 1-7.