The concentration of enteric methane from cattle fed different fibre level

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Abstract. The study aimed to predict the concentration on cattle’s enteric methane fed with different crude fibre (CF) content. Twenty-four male Bali cattle were fed with three different rations of A (low CF), B (medium CF) and C (high CF). At the end of the study, the rumen fluid was taken at 0 and 3 h after feeding, analysed for partial VFA to predict the concentration of enteric methane formed. The experiment design was a completed randomized design with three treatments and eight replications. Prediction of methane concentration at 0 and 3 h and the increase were not differed among treatments. At 0 h, the predicted methane concentrations of treatments A, B and C (mean ± SEM) were 12.59 ± 0.561 mmol L\(^{-1}\), 9.53 ± 1.737 mmol L\(^{-1}\) and 9.06 ± 1.041 mmol L\(^{-1}\), respectively. While at the 3 h were 16.64 ± 1.19 mmol L\(^{-1}\), 14.2 ± 1.052 mmol L\(^{-1}\) and 16.24 ± 1.495 mmol L\(^{-1}\), respectively. The increasing methane concentration up to 3 h was 42.74 ± 16.895%, 79.39 ± 16.332% and 58.00 ± 11.120%. It was concluded that the difference in fibre ration content had not affected the concentration of methane up to 3 h after feeding.

1. Introduction

Cattle, buffalo, goat and sheep are the animals that dominate the livestock sector and they have a unique digestive system classified as ruminants. Ruminants have a complex forestomach as a place for feed fermented by microorganisms and their fermentation products can be utilized by the host animal as nutrition resources. In the fermentation process, methane is emitted and will be released when belching. The methane is known as enteric methane.

Anthropogenic methane emission is important because it is the second largest after carbon dioxide [1]. The production of enteric methane is significant, Cottle et al. [2] reported that in many developed countries, enteric methane compared to methane emissions from the agricultural sector reached 25.7 to 64.0%. Globally, livestock emits methane 40% to 45% of greenhouse gases and 90% are enteric methane [3].

Many efforts have been made by experts to mitigate methane emissions from ruminants because indeed methane formation is also harmful to animals, along with the formation is occurred losing feed energy. The mitigation of enteric methane is by obtaining alternatives to hydrogen sink binders besides methanogen and controlling the methanogen itself [4]. Furthermore, increasing propionate formation in the rumen able to depress the hydrogen sinks become methanogenesis precursors.

Observation of the profile on the partial volatile fatty acids (VFA) formation (acetate, propionate and butyrate, as three major of VFA) is important because it can illustrate how much methane will be formed. Moss et al. [5] suggested that methane enteric production can be calculated through the stoichiometry.
of the formation of fermented VFA, mainly acetate (C2), propionate (C3) and butyrate (C4) with the equation \( \text{CH}_4 = 0.45 \times (\text{C2}) - 0.275 \times (\text{C3}) + 0.40 \times (\text{C4}) \).

Beckman et al. [6] reported that dairy cows fed high starch feed at 3 hours post-feeding produced higher VFA than high fibre feed, but will have a closer value 6 hours later. Schuller et al. [7] stated that low fibre feed tends to decrease acetic and butyric acid production but significantly increases propionic acid. Zhang et al. [8] stated that in the first 4 hours after eating, the high concentrated feed will produce 3 to 4 times more propionate and butyric acid than the high fibre feed, while acetate tends to decrease. This study aimed to predict the concentration of methane through calculations using the variable content of volatile fatty acids formed in the rumen of Bali cattle fed with different fibre content.

2. Materials and methods

Twenty-four male Bali cattle, 3 to 4 years old, weight 300 to 400 kg, each of them were placed in individual pens provided individual feed and water. Cattle were observed for 16 weeks and fed with three different feed treatments; each treatment represented by eight heads. The treatments were:

- Treatment A (low crude fibre ration; <14%)
- Treatment B (medium crude fibre ration; 18 to 19%)
- Treatment C (high crude fibre ration; >22%)

Their composition and nutritional content are shown in table 1.

| Table 1. The ingredients, compositions and nutritional value of the treatment ration |
|---------------------------------|-----------------|-----------------|-----------------|
| Ingredient                      | Treatment ration-composition (% dry matter) |
|                                 | A (%) | B (%) | C (%) |
| Elephant grass                 | 20    | 35    | 50    |
| Palm oil frond                 | 1     | 1     | 1     |
| CaCO₃                          | 4     | 4.5   | 5.2   |
| NaCl                           | 16    | 5     | 8     |
| Rice bran                      | 8     | 15    | 23    |
| Cassava chips                  | 20    | 16    | 11    |
| Copra                          | 8     | 4     | 8     |
| Wheat pollard                  | 10    | 23    | 38    |
| Coffee husk                    | 8     | 11    | 5.95  |
| Palm kernel meal               | 69.24 | 65.57 | 59.38 |
| Tapioca byproduct              | 69.24 | 65.57 | 59.38 |
| Urea                           | 0.5   | 0.8   | 0.8   |

At the end of the study, rumen fluid was collected at 0 and 3 hours after feeding and analysed for partial VFA content (acetate, propionate and butyrate). The VFA content was used to predict the concentration of enteric methane using the formula Moss et al. [5], with the equation:
The calculation of the three main VFA resulted in the methane concentration, the values are shown in Table 2. There was no difference in methane concentrations between treatments at either the 0th hour or the 3rd hour after feeding, but there were differences between the methane concentrations before and after feeding.

| Treatment       | Methane 0 h (mmol L⁻¹) | Methane 3 h (mmol L⁻¹) | P-value (pre-post feeding) |
|-----------------|------------------------|------------------------|---------------------------|
| A (low crude fibre) | 12.59 ± 1.737          | 16.64 ± 1.495          | 0.058                     |
| B (medium crude fibre) | 9.53 ± 1.041          | 16.24 ± 1.052          | 0.001                     |
| C (high crude fibre)    | 9.06 ± 0.561          | 14.2 ± 1.190           | 0.000                     |

Heinrichs et al. [9] reported that VFA was formed for 24 hours with a certain pattern; generally, it will increase rapidly up to 4 to 6 hours post-feeding then will decrease with a relatively flat slope until the 20 to 22 hours. While Bannink et al. [10] and Norgaard et al. [11] observed that the peak of VFA production tended at 3 to 4 hours after feeding. At the 0 hour, treatment A, the concentration of methane tended to be higher compared to the other two treatments. It was possible since the relatively high concentration of methane in the low fibre feed treatment was related to the faster rumen turnover and faster passage of the ingesta out of the rumen resulting in reduced rumen content, this condition caused cattle to get hungry faster and eating soon. Silva et al. [12] said that digestion duration and fiber passages affected the low removal of rumen contents then limit feed intake.

Methane concentration at 0 and 3 hours after feeding, has a lower value than the results observed by Viennasay et al. [13] who observed replacing rice bran with Tamarin seed meal. The concentration of CH₄ at 0 hours was 24.24 to 25.12 mmol L⁻¹ and at 4 hours was 19.28 to 22.56 mmol L⁻¹. The high concentration of CH₄ as reported by Viennasay et al. [13], it most likely caused by the nutritional content of the feed given which was better and contains high soluble feed; it contained crude protein 15.8 to 16.0% and NDF only 21.8 to 25.4%. On similar observations, Kang et al. [14] obtained a methane concentration of 17.0 to 22.0 mmol L⁻¹.

Methane concentrations reported by Norrapoke et al. [15] was even higher, namely 26.8 to 28.0 mmol L⁻¹; [16] 26.3 to 33.2 mmol L⁻¹. The greater value of both studies was probably due to the difference of sampling, they accumulated rumen fluid after 24 to 48 hours of in vitro fermentation.

The increase in methane content in the first three hours after feeding is shown in table 3. There was no difference in the increase in methane concentration between treatments, but treatment A seemed got the lowest increase in methane concentration 4.05 ± 1.783 mmol L⁻¹ followed by treatment C (5.14 ± 0.999 mmol L⁻¹) and B (6.70 ± 0.994 mmol L⁻¹).

Methane concentration increases along with the rising of acetic acid and butyric acid concentrations, according to the equation Moss et al. [5] and the profile of VFA production in the rumen of cattle in general. It appeared that the increase of methane concentration was relatively small; however, Nunoi et
al. [13] reported a decrease in methane concentration at 4 hours after feeding compared to 0 hours, the values were 2.56 to 4.96 mmol L\(^{-1}\) or decreased 10.19 to 20.46%. Meanwhile, Wang et al. [8] found a quite high increasing methane concentration 7.89 in high concentrate feed (28.29%) and 14.61 (42.35%) in high fibre feed.

### Table 3. The increase concentration of methane at 3 hours after eating

| Treatment            | Increase methane concentration (mmol L\(^{-1}\)) | Ratio Increase methane concentration (%) |
|----------------------|-----------------------------------------------|----------------------------------------|
| A (low crude fibre)  | 4.05 ± 1.783                                   | 42.74 ± 16.895                         |
| B (medium crude fibre)| 6.70 ± 0.994                                   | 79.39 ± 16.323                         |
| C (high crude fibre) | 5.14 ± 0.999                                   | 58.0 ± 11.120                          |

### 4. Conclusions

The pattern of methane formation by the cattle is quite normal, it indicated by the increased methane concentration in most of the animals after feeding, however, it seemed that the differences in fibre feed content had not compactly affected the methane concentration in the rumen up to 3 hours after feeding.

### References

[1] Chang J, Peng S, Ciaos P, Saunois M, Dangal S R S, Herrero M, Havlik P, Tian H and Bousquet P 2019 Revisiting enteric methane emissions from domestic ruminants and their \(\delta^{13}\)C\(_{\text{CH}_4}\) source signature *Nature Communications* \textbf{10}(3420) 1-14

[2] Cottle D J, Nolan J V and Wiedemann S G 2011 Ruminant enteric methane mitigation: a review *Animal Production Science* \textbf{51} 491–514

[3] Meale S J, Mcallister T A, Beauchemin K A, Harstad O M and Chaves A V 2012 Strategies to reduce greenhouse gases from ruminant livestock *Actam Agriculturae Scandinavica, Section A-Animal Science* \textbf{62}(4) 199-211

[4] Kobayashi Y 2010 Abatement of methane production from ruminants: trends in the manipulation of rumen fermentation *Asian-Aust J Anim Sci* \textbf{23}(3) 410-416

[5] Moss A R, Jouany J P and Newbold J 2000 Methane production by ruminants: its contribution to global warming *Ann Zootech* \textbf{49} 231-253

[6] Beckman J L and Weiss W P 2005 Nutrient digestibility of diets with different fiber to starch ratios when fed to lactating dairy cows *J Dairy Sci* \textbf{88} 1015-1023

[7] Sutton J D, Dhanoa M S, Morant S V, France J, Napper D J and Schuller E 2003 Rates of production of acetate, propionate and butyrate in the rumen of lactating dairy cows given normal and low-roughage diets *J Dairy Sci* \textbf{86} 3620-3633

[8] Wang L, Zhang G, Li Y and Zhang Y 2020 Effects of high forage per concentrate diet on volatile fatty acid production and the microorganisms involved in VFA production in cow rumen *Animals* \textbf{10}(223) 1-12 doi:103390/ani1002022

[9] Pino F, Mitchell L K, Jones C M and Heinrichs A J 2018 Comparison of diet digestibility, rumen fermentation, rumen rate of passage and feed efficiency in dairy heifers fed ad-libitum versus precision diets with low and high quality forages *Journal of Applied Animal Research* \textbf{46}(1) 1296-1306

[10] Hatew, B, Podesta S C, Laar H V, Pellikaan W F, Ellis J L, Dijkstra J and Bannink A 2015 Effects of dietary starch content and rate of fermentation on methane production in lactating dairy cows *J Dairy Sci* \textbf{98} 486-499

[11] Schulze A K S, Storm A C, Weisbjeng M R and Norgaard P 2017 Effects of forage neutral detergent fibre and time after feeding on medial and ventral rumen pH and volatile fatty acids concentration in heifers fed highly digestible grass/clover silages *Animal Production Science* \textbf{57} 129–132
[12] Sousa D O, Mesquita B D S, Pires A V, Santana M H D A and Silva L F P 2017 Effects of fibre digestibility and level of roughage on performance and rumen fermentation of finishing beef cattle *Trop Anim Health Prod* 49(7) 1503-1510 DOI: 10.1007/s11250-017-1353-1

[13] Nunoi A, Wanapat M, Foiklang S, Ampapon T and Viennasay B 2018 Effects of replacing rice bran with tamarind seed meal in concentrate mixture diets on the changes in ruminal ecology and feed utilization of dairy steers *Tropical Animal and Production* 51(3) 523-528. DOI: 10.1007/s11250-018-1719-z

[14] Phesatcha B, Wanapat M, Phesatcha K, Ampapon T and Kang S 2016 Supplementation of Flemingia macrophylla and cassava foliage as a rumen enhancer on fermentation efficiency and estimated methane production in dairy steers *Trop Anim Health Prod* 48(7) 1449-1454

[15] Foiklang S, Wanapat M and Norrapoke T 2016 In vitro rumen fermentation and digestibility of buffaloes as influenced by grape pomace powder and urea treated rice straw supplementation *Animal Science Journal* 87 370-377

[16] Giang N T T, Wanapat M, Phesatcha K and Kang S 2016 Level of Leucaena leucocephala silage feeding on intake, rumen fermentation and nutrient digestibility in dairy steers *Trop Anim Health Prod* 48(4)