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# Performance and Estimation of Enteric Methane Emission from Fattening Vietnamese Yellow Cattle Fed Different Crude Protein and Concentrate Levels in the Diet

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**Abstract** | The objectives of this study were to estimate of methane emission from Vietnamese local fattening cattle fed different crude protein (CP) levels in the concentrate (experiment 1) and concentrate levels in the diet (experiment 2). Twenty four cattle with initial live weight (LW) of 150.3 ± 11.8 kg were used in the first experiment and 24 other cattle with initial LW of 145.1 ± 9.8 kg were used in the second experiment. Randomized complete block design was used in both experiments. In the first experiment, concentrate with four CP levels (10, 13, 16 and 19%) was fed at 1.5% of LW. In the second experiment, concentrate was fed at 1.0, 1.4, 1.8 and 2.2% of LW. In addition, in both experiments, cattle was fed with 5 kg native grasses/day (fresh basic) and rice straw was fed ad libitum. Enteric methane emission was estimated by the ruminant model. Initial inputs to the model were i) animal characteristics (age, body weight) ii) feed consumption and iii) the chemical composition of each feed ingredient. The study revealed that dry matter (DM) intake, meat productivity were effected by CP levels in the concentrate ($P<0.05$). Similarly, DM intake, meat productivity increased ($P<0.01$) linearly with increased concentrate levels. Increasing the CP level in the concentrate or the concentrate level in the diet resulted in decreased methane emission intensity (kilogram of product). Appropriate CP levels in the concentrate or the concentrate levels in the diet can be sonsidered as a solution to improve animal productivity while decreasing methane emissions per unit product of cattle production.

**Keywords** | Methane, Greenhouse gas, Vietnam, Local cattle

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## INTRODUCTION

According to Intergovernmental Panel on Climate Change (IPCC), every year livestock production in which mainly ruminant production has methane emission by one-third of global methane emission, and methane gas have global warming potential higher 25-29 times compared to $CO_2$ (IPCC, 2007). Mitigation methane emission to reduce greenhouse gases but not affect performance of animal is one of strategies ruminant development on the world (Hristov et al., 2013b). Methane from enteric fermentation is the byproduct of microbes' metabolic activities in the digestive organs. Microbes in anaerobic rumen, especially, play a key role in digesting feed for ruminant, therefore, feed is the most important factor decide the methane emission in animal.

Protein or nitrogen is the key component in ruminants ration and an appropriate CP level is of utmost importance (Bailey et al., 2008). In fattening cattle, high CP level to encourage greater intake and in order to slaughter animals earlier. However, many studies have documented that greater protein levels are related to increased DM intake (Berends et al., 2014) and increased feed intake leads to an

**Table 1:** Ingredients and chemical composition of diets with different crude protein levels in the concentrate (experiment 1)

| Item | Crude protein levels in the concentrate (%) | | | | Native grass | Rice straw |
|---|---|---|---|---|---|---|
| | 10 | 13 | 16 | 19 | | |
| Ingredient (% fresh basis) | | | | | | |
| Rice bran | 35 | 33 | 33 | 33 | - | - |
| Maize | 32.5 | 30 | 30 | 30 | - | - |
| Cassava powder | 30 | 29 | 25 | 17 | - | - |
| Fish meal | 0 | 5 | 8.5 | 16.5 | - | - |
| Urea | 0.5 | 1 | 1.5 | 1.5 | - | - |
| Salt | 1 | 1 | 1 | 1 | - | - |
| Premix vitamin-mineral | 1 | 1 | 1 | 1 | - | - |
| Chemical composition (% of dry matter) | | | | | | |
| Dry matter | 87.3 | 89.5 | 89.3 | 88.6 | 19.2 | 89.8 |
| Organic matter | 94.6 | 93.5 | 91.7 | 89.2 | 87.5 | 87.1 |
| Crude protein | 10.1 | 13.2 | 16.9 | 20.2 | 12.0 | 5.2 |
| Neutral detergent fibre | 21.8 | 19.2 | 22.9 | 18.4 | 64.2 | 72.7 |
| Ash | 5.5 | 6.5 | 8.3 | 10.8 | 12.5 | 12.9 |
| Gross energy (MJ/kg dry matter) | 18.1 | 18.1 | 18.1 | 18.1 | 17.1 | 17.5 |

increase in methane emission (Shibata and Terada, 2010; Chaokaur et al., 2015). Yan and Mayne (2007) found a negetive relationship between methane emission per DM intake or other products unit and dietary CP concentration. In addition, previous studies reported that cattle have increased average daily gain (ADG) when concentrate supplementation increased (Marino et al., 2006; Manni et al., 2013). However, many studies reported that increased concentarte should be used to increase the production of ruminants (Purwin et al., 2016; Ruiz-Albarrán et al., 2016), and is regarded as an effective methane mitigation strategy (Hristov et al., 2013a). Concentrates favor propionate production in the rumen offering an alternative hydrogen sink to methanogenesis, and lower ruminal pH, which in turn inhibits methanogens directly and indirectly, as protozoal inhibition also decreases protozoal-associated methanogenesis (Grainger and Beauchemin, 2011). Concentrates supply greater amounts of digestible nutrients than roughages, increasing animal productivity, and consequently, decreasing CH4 emission intensity (emissions generated for each kilogram of products) (Capper et al., 2009; Muñoz et al., 2018).

The objectives of this study were to estimate the effects of CP levels in the concentrate and the concentrate levels in the diet on feed intake, meat productivity and methane emsision of Vietnamese fattening local cattle.

## MATERIAL AND METHOD

### Experimental Design and Feeding

Twenty four entire male local cattle of approximately 15 to 18 months of age, and liveweight of 150.3 ± 11.8 kg (experiment 1) or 145.1 ± 9.8 kg (experiment 2) were used. In each experiment, the animals were blocked on the basis of live weight (LW) into groups of 4, and allocated at random within each group to treatment. In experiment 1, the treatments consisted of CP levels in the concentrate of 10, 13, 16 and 19%. In experiment 2, treatments contained the concentrate feeding levels at 1.0, 1.4, 1.8 and 2.2% of LW (DM basis). Both experiments, roughage fed to each cattle consisted of ad *libitum* rice straw at night and 5 kg/d of native grass (fresh basis) at 0730 am and 1315 pm, twice daily in 2 equal amounts. Table 1 presents the feed ingredients and nutrient composition of experiment 1. Concentrate allowance for each cattle was 1.5% of LW (DM basis) daily and was adjusted weekly in accordance with changes to the body weight of the cattle. Table 2 shows the nutrient composition of concentrate, grass and rice straw, as well as the chemicals used in experiment 2. Concentrate was fed in 3 equal amounts at 7:15 am, 1:00 pm and 4:30 pm. When residue occurred in the next morning, it was weighed and subtracted from the concentrate provided. Drinking water was freely accessible. The experiment lasted for 74 days (experiment 1) and 60 days (experiment 2).

### Data Collection and Estimation of Methane Emission

The intake of roughage and concentrate of each cattle were recorded daily. Live weight of cattle was measured at the begining and at the end of each experiment. At the end of each experiment, all animals were slaughtered to determine the carcass weight proportion, lean meat proportion and crude protein content in the meat. Based on the live

**Table 2:** Ingredients and chemical composition of diets of experiment 2

| Item | Concentrate | Native grass | Rice straw |
|---|---|---|---|
| Ingredient (% fresh basis) | | | |
| Rice bran | 33 | - | - |
| Maize | 30 | - | - |
| Cassava powder | 25 | - | - |
| Fish meal | 8.5 | - | - |
| Urea | 1.5 | - | - |
| Salt | 1 | - | - |
| Mineral – vitamin premix* | 1 | - | - |
| Chemical composition (% of dry matter) | | | |
| Dry matter | 85.9 | 21.8 | 87.5 |
| Organic matter | 92.3 | 88.9 | 87.2 |
| Neutral detergent fibre | 16.6 | 58.4 | 65.8 |
| Crude protein | 15.7 | 12.3 | 5.4 |
| Ash | 7.7 | 11.1 | 12.8 |
| Gross energy (MJ/kg dry matter) | 18.1 | 17.6 | 16.8 |

weight gain, carcass weight proportion, lean meat proportion and the crude protein content in the meat, the carcass weight, lean meat weight and edible protein increased during the experimental period were measured.

Enteric methane emission was estimated by ruminant model (Herrero et al., 2013; Ramírez-Restrepo et al., 2017). Ruminant model is designed to predict protential intake, digestion, animal performance and enteric methane production of individual ruminant, comsuming forages, grains and other supplements. Enteric methane produced are calculated based on the quantities of different substrates fermented using the stoichiometries (Herrero et al., 2013). A dynamic component of the model estimates feed intake and supply of nutrients to the animal from knowledge of the fermentation kinetics and passage of feed constituents (carbohydrate and protein) through the gastrointestinal tract. A static component of the model determines the animal's response to nutrients in terms of growth production. Validations have been carried out for more than 80 tropical and temperate diets and the results suggest that the model has the required accuracy not only as a research tool but also for providing decision support at the farm level (Herrero, 1997). Initial inputs to the model in this study were i) animal characteristics (age, body weight) ii) feed consumption of each animal; and iii) the chemical composition of the feed (Herrero et al., 2013). Output of ruminant model is enteric methane emission factor of cattle. The model has been previously used for estimating methane emission factors of the tropical livestock (Shikuku et al., 2017; Ramírez-Restrepo et al., 2017).

### Statistical Analysis

Statistical analyses were performed using the General Linear Models procedure of SPSS 16.0. Data were analysed using the model $Y_{ijk} = \mu + P_i + K_j + e_{ijk}$, where $Y_{ijk}$ is the observation from animal k, receiving treatment i, in block j; μ is the overall of mean; $P_i$ is the effect of the crude protein level in concentrate in experiment 1, or the effect of concentrate level in experiment 2 (i= 1, 2, 3, 4); $K_j$ is the effect of block (j=1, 2, 3, 4, 5, 6) and $e_{ijk}$ is the residual effect. The differences between means were compared using a least significant difference method (LSD). Statistical difference was declared at P<0.05.

## RESULTS

### Dry Matter Intake, Animal Growth and Meat Productivity

The CP levels in the concentrate significantly affected the DM intake (P<0.05). The ADG of cattle had a positive linear relationship with the CP level in the concentrate; however, significant differences were found only between 10% CP compared to other CP levels (Table 3). Total DM intake increased linearly as the levels of the concentrate increased and ranged from 4.42 to 5.70 kg/d (P<0.001), The ADG increased (P<0.001) linearly with the increased levels of the concentrate in the diet (Table 4).

The CP levels in the concentrate and the concenrate levels in the diet significantly afffected (P<0.01) carcass weight (CW), lean meat weight (i.e CW x proportion raw boneless meat) and edible protein (i.e. lean meat weight x raw meat protein content, 0.22, 0.23, 0.22, and 0.21 factor for the treatment of 10, 13, 16 and 19% CP in the concentrate, respectively, and 0.23, 0.24, 0.22 and 0.22 factor for the treatment with 1.0, 1.4, 1.8 and 2.2% BW concentrate,

**Table 3:** Feed intake, live weight gain, meat productivity and methane emission from Vietnam local cattle during 74 days fattening with different protein levels in the concentrate

| Items | CP levels in concentrate (%) | | | | SEM | P |
|---|---|---|---|---|---|---|
| | 10 | 13 | 16 | 19 | | |
| Animal on feed | | | | | | |
| Concentrate intake (kg DM/day) | 2.34[a] | 2.64[b] | 2.62[b] | 2.68[b] | 0.096 | 0.023 |
| Forage intake (kg DM/day) | 2.22 | 2.27 | 2.42 | 2.37 | 0.103 | 0.321 |
| Total DM intake ( kg/day) | 4.57[a] | 4.90[b] | 5.03[b] | 5.05[b] | 0.10 | 0.014 |
| Initial live weight (kg) | 146.0 | 150.2 | 151.8 | 153.4 | 1.236 | 0.064 |
| Final live weight (kg) | 189.0[a] | 201.1[b] | 208.0[b] | 210.6[b] | 3.291 | 0.001 |
| Live weight gain (kg) | 43.1[a] | 50.9[b] | 56.2[b] | 57.2[b] | 2.202 | 0.002 |
| Average daily gain (kg/day) | 0.58[a] | 0.69[b] | 0.76[b] | 0.77[b] | 0.030 | 0.001 |
| Carcass weight proportion (%) | 46.6 | 47.4 | 48.0 | 47.9 | 0.900 | 0.710 |
| Carcass weight* (kg) | 20.0[a] | 24.1[b] | 27.1[b] | 27.4[b] | 1.058 | 0.001 |
| Lean meat weight* (kg) | 14.3[a] | 17.3[b] | 19.5[b] | 19.6[b] | 0.794 | 0.001 |
| Edible protein* (kg) | 3.15[a] | 3.91[b] | 4.34[b] | 4.11[b] | 0.175 | 0.001 |
| Calculated methane emission | | | | | | |
| Total emission (kg/animal/day) | 0.078[a] | 0.084[bc] | 0.082[b] | 0.086[c] | 0.001 | 0.001 |
| Total emission (kg/animal/74 days) | 5.74[a] | 6.21[bc] | 6.05[b] | 6.36[c] | 0.061 | 0.001 |
| Emission intensity (kg/kg average daily gain) | 0.14[a] | 0.13[ab] | 0.11[b] | 0.11[b] | 0.006 | 0.023 |
| Emission intensity (kg/kg carcass weight) | 0.30[a] | 0.26[ab] | 0.23[b] | 0.24[b] | 0.012 | 0.005 |
| Emission intensity (kg/kg edible protein) | 1.88[a] | 1.64[b] | 1.41[b] | 1.58[b] | 0.079 | 0.007 |
| $CH_4$ efficiency (kg $CO_2$eq/kg carcass weight) | 7.42[a] | 6.58[ab] | 5.69[b] | 5.90[b] | 0.304 | 0.005 |
| $CH_4$ efficiency (kg $CO_2$eq/kg edible protein) | 47.0[a] | 41.0[b] | 35.4[b] | 39.4[b] | 1.980 | 0.007 |

[abc] Values on the same row with different superscripts differ ($P<0.05$)

*Estimation carcass weight, lean meat weight and edible protein incresed in the experiment period (74 days)

**Table 4:** Feed intake, live weight gain, meat productivity and methane emission from local cattle during 60 days fattening with different concentrate levels in the diet

| Items | Concentrate levels (% BW) | | | | SEM | P |
|---|---|---|---|---|---|---|
| | 1.0 | 1.4 | 1.8 | 2.2 | | |
| Animal on feed | | | | | | |
| Concentrate intake (kg DM/day) | 1.53[a] | 2.23[b] | 2.80[c] | 3.49[d] | 0.06 | 0.001 |
| Forage intake (kg DM/day) | 2.90[a] | 2.67[b] | 2.30[c] | 2.22[c] | 0.05 | 0.001 |
| Total DM intake (kg/day) | 4.42[a] | 4.90[b] | 5.10[b] | 5.70[c] | 0.071 | 0.001 |
| Initial live weight (kg) | 146.0 | 145.8 | 144.6 | 144.1 | 1.053 | 0.515 |
| Final live weight (kg) | 176.4[a] | 191.0[b] | 193.9[b] | 206.4[c] | 2.473 | 0.001 |
| Live weight gain (kg) | 30.4[a] | 45.2[b] | 49.3[b] | 62.3[c] | 2.354 | 0.001 |
| Average daily gain (kg/day) | 0.51[a] | 0.75[b] | 0.82[b] | 1.04[c] | 0.039 | 0.001 |
| Carcass weight proportion (%) | 46.8 | 47.2 | 49.3 | 48.4 | 0.300 | 0.052 |
| Carcass weight* (kg) | 14.2[a] | 21.4[b] | 24.3[b] | 30.2[c] | 1.102 | 0.001 |
| Lean meat weight* (kg) | 10.4[a] | 15.6[b] | 17.3[b] | 21.5[c] | 0.855 | 0.001 |
| Edible protein* (kg) | 2.38[a] | 3.86[b] | 3.76[b] | 4.75[c] | 0.202 | 0.001 |
| Calculated methane emission | | | | | | |
| Total emission (kg/animal/day) | 0.084[a] | 0.097[b] | 0.11[c] | 0.12[d] | 0.001 | 0.001 |
| Total emission (kg/animal/60 days) | 5.02[a] | 5.83[b] | 6.44[c] | 7.26[d] | 0.070 | 0.001 |
| Emission intensity (kg/kg average daily gain) | 0.17[a] | 0.13[b] | 0.13[b] | 0.12[b] | 0.007 | 0.001 |
| Emission intensity (kg/kg carcass weight) | 0.36[a] | 0.28[b] | 0.27[b] | 0.24[b] | 0.015 | 0.001 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Emission intensity (kg/kg edible protein) | 2.18[a] | 1.57[b] | 1.72[b] | 1.53[c] | 0.102 | 0.002 |
| $CH_4$ efficiency (kg $CO_2$eq/kg carcass weight) | 9.03[a] | 7.03[b] | 6.65[b] | 6.03[b] | 0.364 | 0.001 |
| $CH_4$ efficiency (kg $CO_2$eq/kg edible protein) | 54.6[a] | 39.2[b] | 42.9[b] | 38.3[b] | 2.554 | 0.002 |

[abcd] Values on the same row with different superscripts differ (P<0.05)

*Estimation carcass weight, lean meat weight and edible protein incresed in the experiment period (60 days)

respectively (Dung et al., 2016) (Table 3 and Table 4).

### Predicted and Calculated Methane Emission

The model showed that the CP levels in the concentrate and the concentrate levels significantly afffected (P<0.01) enteric methane emission (Tables 3 and 4). Similarly, methane emission intensities (kg $CH_4$/ADG, kg $CH_4$/CW and kg $CH_4$/edible protein) and methane efficiencies (kg $CO_2$eq/kg CW and kg $CO_2$eq/kg dible protein) were significantly affected by different CP levels in the concentrate and concentrate levels (Tables 3 and 4). The methane emission intensity (kg $CH_4$/kg ADG) declined curvilinearly with the crude protein intake (Figure 1) and the amount of concentrate intake (Figure 2).

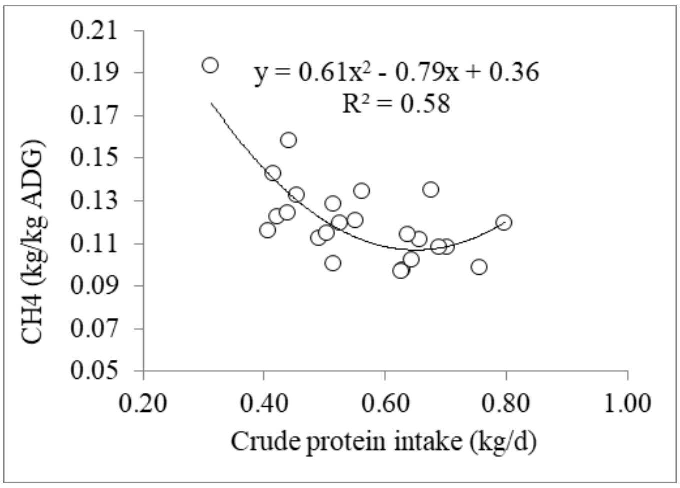


**Figure 1:** Relationship between crude protein intake and methane emission intensity (kg/kg ADG)

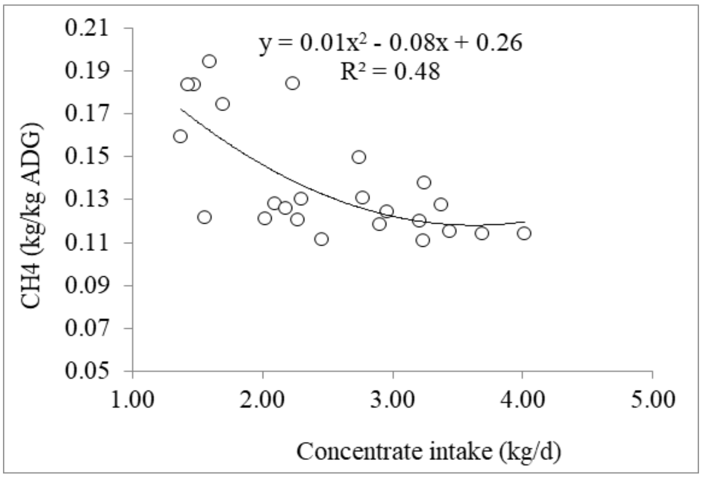


**Figure 2:** Relationship between concentrate intake and methane emission intensity (kg/kg ADG)

## DISCUSSION

The DM intake was improved by increasing the CP level in the concentrate. This observation is in agreement with previous studies (Paengkoum and Tatsapong, 2009; Chen et al., 2010). However, other studies (Archibeque et al., 2007; Chantiratikul et al., 2009) reported that CP levels had no significant effect on DM intake. These variations might have been caused by the different feed resources used in the respective experiments, such as the types of roughage and the ingredients of concentrate. The amount of concentrate intake had positive effects on DM intake (experiment 2). These observations are similar to the conclusion of many researchers (Manni et al., 2013; Arriola et al., 2011).

The CP levels in the concentrate and the concentrate levels significantly affected CW, lean meat weight and edible protein. Previous studies (Bailey al., 2008; Gleghorn et al., 2004) reported that increasing dietary CP concentration increased CW. In another study, Iwamoto et al. (2010) concluded that increasing dietary CP level from 12 to 18% did not significantly affect CW in Japanese Black steers. In the present study, the CP level affected CW, the differences between studies might have been caused by the different protein sources used in the respective experiments, slaughtering bodyweight and cattle genotypes. The effect of the concentrate level on carcass characteristic was reported by several authors. In a study of Jian et al. (2013) feeding 85% concentrate in the diet during the finishing phase produced greater CW than feeding 70% concentrate in the diet for Jersey steers. However, Lage et al. (2012) could not find the effects of the concentrate supplementation on CW. Based on results of current research, the effect of the concentrate level on carcass characteristic it not conclusive and it may also depend on the life stage of the animal when dietary treatments were applied, slaughtering body weight, feeding management and genotypes (Jiang et al., 2013).

Enteric methane emission of cattle in the present study ranged from 0.078 to 0.12 kg/animal/day, these results were lower than that of the recommendation of IPCC (2006) which documented that enteric methane emission of cattle in Asia is 0.13 kg/head/day (47 kg/year). Increasing CP levels or concentrate levels resulted in increased methane emission. Recent studies have demonstrated that greater protein levels are related to increased DM intake (Berends et al., 2014) and increased feed intake leads to an increase in methane production (Shibata and Terada, 2010; Chaokaur et al., 2015). Similarly results were reported for the increase in the amount of concentrate intake for cattle. In the present study, the CP levels in the concentrate significantly affected methane emission per products unit (ADG, CW, adible protein), however, significant effects could only be found between 10% compared to other CP levels. The effects of protein levels on methane emission are not consistent in the literature, Yan and Mayne (2007) found a nagetive relationship between methane emission per DM intake or other products unit and dietary CP concentration. However, Hynes et al. (2016), Menezes et al. (2016) reported that, CP levels did not affect methane emission per product unit. The effect of CP levels on methane emission is likely not solely dependent on dietary CP concentration, but a result of the subsequent change in other dietary factors (e.g., fiber and starch concentrations) (Manezes et al., 2016).

Increasing concentrate levels in the diet resulted in decreased methane emission per product unit. These finding were similar to other researchers, Grainger and Beauchemin (2011) reported that, concentrates favor propionate production in the rumen offering an alternative hydrogen sink to methanogenesis, and lower ruminal pH, which in turn inhibits methanogens directly and indirectly, as protozoal inhibition also decreases protozoal-associated methanogenesis. In addition, Capper et al. (2009), Muñoz et al. (2018) documented that, concentrates supply greater amounts of digestible nutrients than roughages, increasing animal productivity, and consequently, decreasing CH4 emission intensity (emissions generated for each kilogram of products). Many studies reported that, supplementation of diets with concentrates are widely used to increase the production of ruminants (Purwin et al., 2016; Ruiz-Albarrán et al., 2016), and is regarded as an effective methane mitigation strategy (Hristov et al., 2013a).

## CONCLUSION

Incrasing CP levels or concentrate levels in the diet resulted in increased DM intake, meat productivity and decreased methane emission intensity (emissions generated for each unit of product). Appropriate protein levels in the concentrate (the diet) or the concentrate level in diet may be a solution to improve animal productivity while decreasing methane emission/products unit of cattle.

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## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## AUTHORS CONTRIBUTION

Dinh Van Dung- Writing the manuscript, designing experiments, Data collection, Data analyses.
Le Dinh Phung- Designing Experiments, Revising the manuscript, Data analyses.
Hynek Roubik- Writing and Revising the manuscript.

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