Agriculture, Ecosystems and Environment 199 (2015) 225–230

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

# Effects of feeding level on methane emissions and energy utilization of Brahman cattle in the tropics

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ARTICLE INFO

*Article history:*
Received 4 June 2012
Received in revised form 9 September 2014
Accepted 10 September 2014
Available online 14 October 2014

*Keywords:*
Ruminant
Energy
Methane
Tropical
*Bos indicus*
Brahman

ABSTRACT

The release of methane from ruminant livestock is a problem not only because it contributes to greenhouse gas emissions but also because it affects feed energy utilization and animal production efficiency. The objective of this experiment was to determine the effects of feeding level on methane emission and energy utilization of Brahman cattle (*Bos indicus*). Sixteen 2-year-old Brahman steers were housed in individual pens for a 70-day feeding experiment. Dietary treatments were applied in a randomized complete block design with four replications and four feeding levels (M, 1.4 × M, 1.8 × M, and *ad libitum*; where M represents a metabolizable energy requirement for maintenance. The animals were placed in a metabolic cage equipped with a ventilated head box system to determine the total collection digestibility and energy balance. Energy partitioning in response to feeding level significantly linearly increased. Although the total tract digestibility of dry matter, organic matter, crude protein, and neutral detergent fiber were affected slightly depressed, total feed intake, nutrient intake, and energy intake increased dramatically as feeding levels increased. Methane emission rate decreased (from 11.5 to 7.3%) with increasing feeding level, yet these values are much higher than the IPCC recommended value (6.5%) for calculation of national inventory of enteric methane emissions. A daily metabolizable energy requirement for maintenance was estimated at 435 kilojoules of metabolizable energy per kilogram of metabolic body weight, and the estimated efficiency of the utilization of metabolizable energy for growth was 0.54. Our study found that increasing feeding level increased average daily gain of Brahman cattle and the observed increased energetic efficiency was attributed to reduced energy output in urine, methane and heat production.



## 1. Introduction

Feeding systems that do not meet animals' energy requirements may result in the failure of livestock to meet expectations of performance. Enteric methane emissions from ruminant supply chains are problematic with respect to the energy utilization efficiency of animal feed as well as environmental sustainability impact due to such emissions being a major greenhouse gas source contributes to climate change. The Food and Agriculture Organization of the United Nations (FAO) reported that greenhouse gas emissions from livestock sector represent 14.5% of global human-induced greenhouse gas emissions and that the emissions from beef production represent 41% of sector's (Gerber et al., 2013). Brahman cattle are the predominant breed for beef production in tropical zones, where feeding systems generally depend on low quality forage resources that often are deficient in nitrogen and digestible energy, hence limiting animal productivity. Energy requirement is a function of energetic efficiency, and so energetic efficiency must be known in order to determine the energy supply needed from a diet to meet production targets (ARC, 1980; Kearl, 1982; NRc, 2000).

However, research on energy metabolism of cattle in humid tropical condition is still scarce. The Intergovernmental Panel on Climate Change (IPCC) guidelines for a Tier 2 approach set a default value of 6.5% for the proportion of methane energy emission to gross energy intake (methane emissions rate), chosen on the basis of limited data from *B. indicus* (IPCC, 2006; Kurihara et al., 1999; Steinfeld et al., 2006). The objective of this experiment was to determine the effects of feeding level on methane emission and energy utilization of Brahman cattle.

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http://dx.doi.org/10.1016/j.agee.2014.09.014
0167-8809/

## 2. Materials and Methods

The experiment was conducted at the Khon Kaen Animal Nutrition Research and Development Center, Khon Kaen province, Thailand (latitude 16.34 °N, longitude 102.82 °E) from November 19, 2006, to February 15, 2007. The average temperature in the study site was 25.3 ± 1.9 °C, the average relative humidity was 67.2 ± 1.9%, and the average temperature humidity index was 74.0 ± 12.9. All animal-related procedures followed the Guide for the Care and Use of Experimental Animals (Curtis and Nimz, 1988) and were conducted with the permission of the Graduate School, Khon Kaen University.

### 2.1. Animal, experimental design and diet

Sixteen Brahman steers, with an average body weight of 342.7 ± 16.2 kg and age of 2 years, were used for a 70-day feeding trial following after a pre-experimental period for 15 days. The animals were blocked by body weight in a randomized complete block design in equal numbers and assigned randomly to one of four feeding levels of a mixed diet (Table 1) containing pangola grass (*Digitaria eriantha*) that as the main forage source. The four feeding levels were: M, 1.4 × M, 1.8 × M, and *ad libitum*, where M represents the dairy maintenance requirement of metabolizable energy (450 KJ ME/kgBW$^{0.75}$; Chaokaur et al., 2007). Feed components and analyzed chemical composition of the diets are shown in Table 1.

### 2.2. Animal feeding and management

The animals were housed individually in adjacent holding pens. Clean water and mineral blocks were freely available to the animals at all times. A vitamin supplement ($AD_3E$) was given intramuscularly to all animals at the beginning of the experiments.

Feed was offered in equal amounts twice a day at 0900 and 1600 h. The feed was weighed daily and offered at 0900 h to each animal after the feed residue from the previous day had been removed. The difference between the amount of feed offered and the amount of residue removed was recorded as the amount of daily feed intake. Samples of the feed offered and the residue removed were collected daily and stored in a dry location for later processing and analysis.

The animals were weighed on the first day of the feeding trial and again every 2 weeks in the morning (0800 h) to determine their metabolic body weight (BW$^{0.75}$) for feeding levels. The weight of each animal was regressed against time using linear regression (regression equation: Weight = $a + b \times$ day). The intercept ($a$) was recorded as the adjusted initial weight and the slope ($b$) as the average daily gain.

**Table 1**
Feed component, analyzed chemical composition, and determined energy content of the diet (on a dry matter basis).[a]

| Item | Experimental diet |
|---|---|
| Feed component (%) | |
| Pangola grass hay | 30.0 |
| Cassava chip | 30.0 |
| Rice bran | 21.0 |
| Palm kernel cake | 17.0 |
| Urea | 1.5 |
| Mineral mixed | 0.5 |
| Total | 100 |
| Chemical composition (%) | |
| DM | 92.2 |
| OM | 89.6 |
| CP | 11.5 |
| EE | 5.2 |
| NDF | 36.7 |
| ADF | 19.8 |
| Energy content (MJ/kg) | |
| GE | 16.4 |
| DE | 11.9 |
| ME | 10.1 |

[a] DM, dry matter; CP, crude protein; OM, organic matter; EE, ether extracts; CF, crude fiber; NFE, nitrogen-free extracts; NDF, neutral detergent fiber; ADF, acid detergent fiber; GE, gross energy; DE, digestible energy; ME, metabolizable energy.

### 2.3. Digestion trials

A total collection digestion trial was conducted for 6 days for each block following Schneider and Flatt (1975). The digestion trail was rotated random sequence for each block in the feeding experiment. The amounts of feed offered, feed refused, feces, and urine from each animal were weighed and recorded daily. Urine was collected in buckets containing sufficient $H_2SO_4$ (20% v/v; 200 mL) to maintain pH at <3. Each day, 1-kg samples of feed offered, feed refused, and feces, as well as a 500-mL sample of urine, were sub-sampled from each animal and stored at −20 °C. At the end of each trial, the samples were thawed, pooled for each animal, and mixed thoroughly. Aliquots samples were stored for later processing and analysis.

### 2.4. Indirect calorimeter

An open-circuit indirect calorimeter with a ventilated head box system was used to measure methane emissions, oxygen consumption, and carbon dioxide production for each animal of each block, according to the methods of Suzuki et al. (2008). Briefly, the system consisted of a digestion trial pen, a head cage, a gas sampling and analysis unit, and a data acquisition and processing unit. A flow meter (Nippon Flow Cell Co., Ltd. Japan, model FWH-N-S) was used to record the flow rate and total volume of air flowing out of the respiration chamber. The collected samples of out flowing and incoming air were analyzed for oxygen content using a dual chamber paramagnetic oxygen analyzer (Servomex Pcl. UK, model Xentra 4100), whereas carbon dioxide and methane content using an infrared gas analyzer (Horiba, Japan, model VIA 510). The temperature and humidity of the outflow air were thermorecorded electronically (Espec Mic Corp, Japan, model RS-12). The gas analyzers were calibrated daily against certified gases (Takachiho Chemical Industrial Co. Ltd., Japan). The data recording program used Test-point software (Capital Equipment Corporation, Billerica, Massachusetts, USA). The system allowed the measurement of the concentration of ambient oxygen, carbon dioxide and methane. The calorimetric system was calibrated using the carbon dioxide injection method of releasing a pre-weighed quantity of carbon dioxide gas into the system. The respiratory gas exchange measurements were conducted for three consecutive days (23.5 h per day; from 0930 h to 0900 h of the next day) at day 4, 5 and 6 of the digestion trial.

### 2.5. Chemical analysis

Aliquots samples of feed, feces, and urine that had been collected were dried in a forced-air oven at 60 °C for 72 h and ground to pass through a 1-mm screen. The dry matter (DM), crude protein (CP), ether extract (EE), and ash contents of the offered feed, refused feed, and feces were determined following the Association of Official Analytical Chemists (AOAC, 1990). The nitrogen (N) content of urine was determined following AOAC (1990). The GE contents of feed, orts, feces, and urine were determined in a Shimadzu auto-calculating bomb calorimeter