Metabolisable Energy Values of Beef Cattle Ratio Determined Using In Vitro Gas Production Technique

Kusmartono Kusmartono[1,*], Mashudi Mashudi[1], Poespitasari Hazanah Ndaru[1], Aprilia Dwi Kartika[1], Muhammad Rifki[1] and Kania Ainul Mardhiah[1]

[1] Faculty of Animal Science, Universitas Brawijaya, Malang 65145, Indonesia
*kusmartono_ansi@ub.ac.id

Abstract. This study aimed to evaluate the metabolizable energy (ME) value of beef cattle rations using the in vitro gas production technique. Rumen fluid samples were collected from a slaughterhouse in Malang City and analyzed at the Animal Nutrition and Feed Laboratory, Faculty of Animal Science, Universitas Brawijaya. Nutritional analysis of the forage, specifically elephant grass, showed a dry matter (DM) content of 30.79%, organic matter (OM) 78.29%, crude protein (CP) 6.25%, ether extract (EE) 2.40%, crude fiber (CF) 30.91%, and nitrogen-free extract (NFE) 38.73%. The concentrate feed contained higher nutrient values, with DM 88.51%, OM 88.54%, CP 12.07%, EE 3.48%, CF 18.45%, and NFE 54.54%. Four different rations were formulated with varying forage-to-concentrate ratios. Among them, the T2 treatment (40% elephant grass and 60% concentrate) produced the highest total gas (91.6 ± 2.80 ml/500 mg DM) and ME value (8.7 MJ/kg DM), significantly outperforming the T1 treatment (100% elephant grass). Treatments T3 and T4 also showed improved results, but T2 remained the most effective. These findings indicate that a 40:60 ratio of elephant grass to concentrate optimizes rumen microbial activity, leading to higher gas production and metabolizable energy.

Keywords: concentrate feed, forage, gas production, **metabolizable energy**, nutritional content.

1 Introduction

Livestock farming is fundamental in the global agricultural sector, contributing significantly to economic stability, food security, and rural livelihoods. In Indonesia, the livestock industry plays a vital role in providing employment, improving farmers' incomes, and meeting the growing demand for animal protein. Among various livestock species, cattle farming is particularly important due to its contribution to meat production and its integration with crop farming systems.

Feed quality is a major factor influencing cattle growth performance, affecting weight gain, feed conversion efficiency, and animal health. In traditional Indonesian cattle farming, forage-based diets—mainly composed of elephant grass and other local grasses—are widely used. However, these forages are limited in nutritional value, particularly in protein and energy content, which restricts optimal growth rates.

I. Subagiyo et al. (eds.), *Proceedings of the 11th International Conference of Innovation in Animal Science (ICIAS 2024)*, Advances in Biological Sciences Research 49,
https://doi.org/10.2991/978-94-6463-880-6_40

The use of supplementary concentrate feed has been recognized as an effective strategy to improve nutrient intake and productivity [1]. Concentrates made from cassava waste, copra meal, palm oil meal, and rice bran provide higher levels of protein and energy, promoting more efficient rumen fermentation and increasing metabolizable energy production [2]. The inclusion of energy-dense and protein-rich ingredients such as copra meal and palm oil meal also supports microbial activity and fermentation in the rumen.

Studies have shown that concentrate supplementation at a ratio of 40–60% can significantly increase gas production in the rumen, which serves as an indicator of microbial fermentation and organic matter digestibility [3]. This improvement in fermentation efficiency correlates directly with higher metabolizable energy availability, enhancing feed utilization and accelerating animal growth [4].

Previous research has highlighted the influence of different forage-to-concentrate ratios on gas production and metabolizable energy. [5] reported an increase in gas production from 121.71 ml to 127.46 ml per 500 mg dry matter (DM) with concentrate supplementation, while These findings suggest that adequate concentrate inclusion improves rumen microbial activity and overall cattle performance.

However, despite these positive outcomes, the optimal forage-to-concentrate ratio that maximizes metabolizable energy while maintaining rumen health remains unclear, particularly within smallholder beef cattle systems in Indonesia. Therefore, this study aims to evaluate the metabolizable energy value of different forage-to-concentrate ratios using the in vitro gas production technique to determine the most effective formulation for improving rumen fermentation and energy utilization.

2 Materials and Methods

2.1 Materials

This study investigated the effects of varying forage-to-concentrate ratios on gas production and metabolizable energy in beef cattle feed. The forage used was elephant grass, sourced from Socah District, Bangkalan. The concentrate was formulated using a mixture of cassava waste (40%), copra meal (30%), palm kernel meal (30%), and a mineral mix. Rumen fluid was collected from beef cattle at a local slaughterhouse to be used in the in vitro fermentation process.

2.2 Methods

Field surveys and observations were conducted to collect preliminary information on local feeding practices, including the use of agricultural by-products and legume leaves as feed sources. Based on this survey, feed formulations were developed and analyzed for their chemical composition through proximate analysis and evaluated using the in vitro gas production technique. Four dietary treatments were prepared and tested in triplicate:

T1: 100% Elephant grass and 0% Concentrate.
T2: 40% Elephant grass and 60% Concentrate.
T3: 50% Elephant grass and 50% Concentrate.
T4: 60% Elephant grass and 40% Concentrate.

Each treatment was assessed for dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), crude fiber (CF), nitrogen-free extract (NFE), gas production, and metabolizable energy (ME).

2.3 Variable

1. Gas production method through calculations gas production using the formula:

$$Gas\ production\ (ml/500\ mg\ DM) = \{(Vt - V0) - Vb\} * Factor\ Correction \quad (1)$$

2. Calculation of the value of gas production and the production rate does not use the formula:

$$Gas\ production\ (ml/500\ mg\ DM) = \{(Vt - V0) - Vb\} * Factor\ Correction \quad (2)$$

3. Calculation methods in energy test metabolism using the formula:

$$ME\ (MJ/kg\ DM) = 2{,}2 + 0{,}136 * gas\ production + 0{,}057 * CP + 0{,}0029 * CF \quad (3)$$

2.4 Variable

The data obtained was calculated using the Excel program, while the data was analyzed using a Randomized Block Design (RBD) with 4 treatments and 3 replications. Randomized Block Design (RBD) statistical model.

$$Yij = u + \tau i + \beta j + eij \quad (4)$$

Information;
Ti : The additive effect of the i-th treatment
Bj : Additive influence of the jth group
eij : Influence error test from the ith treatment to the jth group

3 Results and Discussion

The nutritional analysis of elephant grass used in this study showed a dry matter (DM) content of 30.79%, organic matter (OM) 78.29%, crude protein (CP) 6.25%, ether extract (EE) 2.40%, crude fiber (CF) 30.91%, and nitrogen-free extract (NFE) 38.73%. These values differ notably from those reported by [5], who found a lower DM (15.73%) and higher CP (16.31%) content, among others. Such differences are likely due to environmental and agronomic factors, including harvest time, geographic origin, rainfall, and temperature, which can significantly affect forage composition.

Concentrate feed formulated from cassava waste, copra meal, palm oil meal, and rice bran demonstrated higher nutritional values than elephant grass (Table 1). The concentrate recorded a DM of 89.51%, OM of 88.54%, CP of 12.07%, EE of 3.42%, CF of 18.45%, and NFE of 54.54%, aligning with the Indonesian National Standard [6]. Previous studies by [7] and [2] similarly confirmed the nutritional adequacy of agro-industrial by-products as ruminant feed components.

Table 1. Feed nutritional content.

Nutritional Content	Elephant Grass	Cassava Waste	Copra Meal	Palm Oil Meal	Rice Bran	Concentrate
DM (%)	38.79	88.97	87.27	92.48	90.41	89.51
OM (%)	78.29	81.58	90.11	95.99	88.22	88.54
CP (%)	6.25	1.48	22.08	15.52	7.49	12.07
EE (%)	2.40	0.66	1.84	8.66	7.24	3.42
CF (%)	30.91	14.9	20.79	20.79	18.79	18.45
NFE (%)	38.73	64.54	44.68	50.92	55.70	54.54

Concentrate feed utilized in this study, comprising cassava waste, copra meal, palm oil meal, and rice bran, presented higher nutritional value compared to elephant grass. Specifically, the concentrate showed a DM of 88.51%, OM at 88.54%, CP at 12.07%, EE at 3.48%, CF at 18.45%, and NFE at 54.54%. The proximate analysis confirmed that these concentrate ingredients align with the Indonesian National Standard (SNI 3148-2:2009), making them suitable and nutritionally adequate for cattle feeding. Similar nutritional compositions have been reported in previous [7] and [2], highlighting the consistency and reliability of using local agro-industrial by-products as cattle feed.

Table 2. The nutritional content of each treatment.

	Treatments			
Nutrient Content	T1	T2	T3	T4
DM (%)	90.60	89.95	90.06	90.17
OM*	77.15	83.95	82.81	81.67
CP*	6.42	9.79	9.23	8.67
EE*	4.40	3.85	3.94	4.03
CF*	31.76	23.81	25.14	26.47
NFE*	44.57	50.52	49.52	48.53

* in % DM.

Four dietary treatments were systematically formulated, varying in the ratio of elephant grass to concentrate. Treatment 1 (T1) comprised entirely elephant grass, Treatment 2 (T2) had 40% elephant grass with 60% concentrate, Treatment 3 (T3) included 50% elephant grass with 50% concentrate, and Treatment 4 (T4) consisted of 60% elephant grass with 40% concentrate. Nutritional analysis revealed significant differences among these treatments. Notably, T2 contained the highest crude protein content (9.79%), closely followed by T3 (9.23%) and T4 (8.67%). Treatment T1 had the lowest crude protein at 6.42%, indicating the necessity of concentrate supplementation to meet the protein requirements for optimal cattle growth.

The ether extract (EE) varied slightly among treatments, with T1 showing the highest level (4.40%) compared to T2 (3.85%), T3 (3.94%), and T4 (4.03%). These results suggest variations in fat content depending on concentrate ratios. Crude fiber (CF) levels were significantly lower in T2 (23.81%) compared to T1 (31.76%), highlighting that increased concentrate content effectively reduces overall fiber content, thus potentially enhancing digestibility and nutrient absorption in cattle.

Table 3. The gas production of treatments.

Treatment	**Total gas production 48 hours incubation (ml/500 mg DM)**	**B (ml/500 mg DM)**	**C (ml/hour)**
T1	65.1 ± 6.39^{a}	114.0 ± 52.57^{a}	0.022 ± 0.0098^{a}
T2	91.6 ± 2.80^{b}	114.7 ± 21.55^{b}	0.044 ± 0.0245^{b}
T3	85.2 ± 7.50^{b}	99.0 ± 13.97^{b}	0.047 ± 0.0182^{b}
T4	81.4 ± 5.89^{ab}	98.6 ± 6.40^{b}	0.041 ± 0.0150^{b}

In vitro gas production analyses provided critical insights into rumen fermentation efficiency, an essential determinant of feed quality. Table 3 shows total gas production after 48 hours of incubation was significantly affected by the forage-to-concentrate ratio ($P<0.05$). Treatment T2 yielded the highest total gas production at 91.6 ± 2.80 ml/500 mg DM, significantly higher than T1 at 65.1 ± 6.39 ml/500 mg DM. Treatments T3 and T4, with gas productions of 85.2 ± 7.50 ml/500 mg DM and 81.4 ± 5.89 ml/500 mg DM, respectively, also exhibited significantly higher gas production than T1 but were statistically similar to T2.

The significantly increased gas production in treatments containing higher concentrate ratios (T2, T3, T4) compared to forage-only treatment (T1) demonstrates improved rumen fermentation efficiency. These results align with previous findings by [5], which reported elevated gas production levels correlating with increased concentrate supplementation due to enhanced ruminal microbial activity and carbohydrate availability.

Table 4 shows metabolic energy (EM) values significantly different across treatments ($P<0.05$). Treatment T2 showed the highest EM value at 8.7 MJ/kg DM, closely followed by T3 (8.5 MJ/kg DM) and T4 (8.3 MJ/kg DM), with T1 presenting the lowest EM value at 8.0 MJ/kg DM. The elevated EM values in concentrate-rich treatments suggest that increased concentrate proportion enhances energy availability for cattle, promoting better growth and productivity. These findings are consistent with observations [8], who documented a positive correlation between increased concentrate supplementation and improved EM values, subsequently leading to enhanced livestock growth rates.

Table 4. The metabolic energy value of treatments.

Treatment	Metabolic Energy (MJ/kgDM)
T1	8.0 ± 0.04^{a}
T2	8.7 ± 0.39^{b}
T3	8.5 ± 0.35^{b}
T4	8.3 ± 0.44^{ab}

4 Conclusion

The treatment with 40% elephant grass and 60% concentrate (T2) resulted in the highest gas production and metabolizable energy, indicating improved rumen fermentation efficiency and nutrient digestibility. These results highlight the importance of optimizing the forage-to-concentrate ratio to support ruminal microbial activity and enhance feed utilization. From a practical perspective, the 40:60 ratio offers a promising strategy for smallholder cattle farmers to improve cattle productivity by using locally available feed resources more efficiently. Future research is recommended to validate these findings through in vivo trials and assess the economic feasibility of implementing such feeding strategies in real farm conditions.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Menke, K.H. and H. Steingass, Estimation of the energic feed value obtained from chemical analysis an in vitro gas production using rumen fluid. Anim. Res. Dev. 28: 7- 55. (1988)
2. Waldi, L, The Effect of Using Soybean Meal and Coconut Meal in Rations Based on Energy and Protein Synchronization Index on Rumen Microbial Protein Synthesis in Dairy Cows. Journal Of Livestock Science And Production, 1(1), 1-12 (2017)
3. Makkar, H. P. S., M. Blummel and K. Becker, Formation of Complexes Between Polyvinyl Pyrrolidones Orpolyethtlene Glycols and Tannins, and Their Implication in Gasproduction and True Digestibility In In Vitro techniques Britis Journal of Nutrition. 73: 893-913. (1995)
4. McDonald, B. A., Pettway, R. E., Chen, R. S., Boeger, J. M., and Martinez, J. P. 1995. The population genetics of Septoria tritici (teleomorph Mycosphaerella graminicola). Canadian Journal of Botany, 73(S1) : 292-301.

5. Khoiriyah, K., Ahmad, A., and Fitriani, D. 2016. Model pengembangan kecakapan berbahasa anak yang terlambat berbicara (speech delay) (Doctoral dissertation, Syiah Kuala University).
6. SNI 3148-2, Jakarta: National Standardization Agency, (2009)
7. Sedya, I. W., Rinawidiastuti, R., & Iskandar, F, Vitamin E as an antioxidant against rancidity of copra meal. Journal of Agribusiness and Livestock Research, 8(1), 64-72, (2023)
8. Tahuk, P.K., A.A. Dethan and S. Sio, Energy and Nitrogen Balance of Male Bali Cattle Fattened with Greenlot Fattening on People's Farms. Journal of Tropical Animal Science and Technology. 2(1): 23-36, (2020)