Samadi et al./Animal Production. 26 (3): 156-168, 2024
Accredited by Kemendikbudristek Dirjendiktiristek No 225/E/KPT/2022. E-ISSN 2541-5875

A Meta-Analysis to Determine Protein and Energy Requirements for Maintenance and Growth of Cattle in Indonesia

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Abstract. The meta-analysis in this study was conducted to determine the protein and energy requirements of various cattle breeds in Indonesia. A database was compiled from various research articles that involved cattle as the experimental animals, focusing on studies that reported energy and protein intake, initial body weight, and average daily gain (ADG). In total, 57 articles covering different cattle breeds in Indonesia, with 191 data points, were integrated into the database. The database specified different breeds (Aceh, Bali, Madura, Peranakan Ongole (PO), Sumba Ongole (SO), and Local) and sexes. Regressing ADG used to determine maintenance and gain requirements of dry matter, energy, and protein with dry matter intake (DMI), total digestible nutrient intake (TDNI), and crude protein intake (CPI), respectively. An intercept (where ADG= 0 kg/kg MBW/d) and a slope (required nutrient intake per unit ADG) were taken as maintenance and gain requirements, respectively. Results revealed that protein and energy requirement for maintenance (CPm and TDNm) of all cattle breeds varied in values, ranging from 0.0014 to 0.0102 kg/kg MBW/d (Madura and PO breeds) and 0.0232 to 0.0687 kg/kg MBW/d (Aceh and PO breeds), respectively. Each cattle breed in Indonesia has its particular CP and TDN requirements. Both energy and protein requirements for maintenance (CPm and TDNm) and gain (CPg and TDNg) varied in value for each breed.

Keywords: Cattle, Energy, Meta-Analysis, Nutrient Requirement, Protein

Abstrak. Meta-analisis pada penelitian ini dilakukan untuk menentukan kebutuhan protein dan energi dari sejumlah bangsa sapi yang terdapat di Indonesia. Database dikembangkan dari berbagai artikel penelitian yang melibatkan sapi sebagai hewan penelitian dengan perlakuan pakan dan konsumsi energi, konsumsi protein, bobot badan awal dan pertambahan bobot badan. Sebanyak 57 artikel yang terdiri dari 191 data dihimpun menjadi sebuah database. Bangsa sapi yang berbeda (Aceh, Bali, Madura, Peranakan Ongole, Sumba Ongole dan Lokal) dan jenis kelamin disertakan dalam database. Regresi ADG digunakan untuk menentukan kebutuhan pemeliharaan dan pertambahan bahan kering, energi, dan protein dengan asupan bahan kering (DMI), asupan nutrien tercerna total (TDNI), dan asupan protein kasar (CPI). Kebutuhan hidup pokok didapatkan melalui nilai intersep regresi (di mana PBB= 0 kg/kg bobot badan metabolik [BBM]/hari) sedangkan kebutuhan pertumbuhan adalah nilai kemiringan (konsumsi per unit PBB) dari persamaan regresi. Hasil menunjukkan bahwa kebutuhan protein dan energi untuk hidup pokok (CP_m dan TDN_m) dari semua bangsa sapi memiliki nilai yang beragam, mulai dari 0.0014 hingga 0.0102 kg/kg MBW/d (sapi Madura dan PO) dan 0.0232 hingga 0.0687 kg/kg MBW/d (sapi Aceh dan PO) secara berurutan. Dapat disimpulkan bahwa setiap bangsa sapi di Indonesia memiliki kebutuhan protein dan energi yang spesifik untuk hidup pokok maupun pertumbuhan.

Kata Kunci: Energi, Kebutuhan Nutrisi, Meta-Analisis, Protein, Sapi

Introduction

Feed is a critical factor influencing animal productivity. It is well known that in Indonesia, feed formulation to meet the nutrient requirements of both non-ruminant animals (such as poultry and swine) and ruminant animals (such as dairy and beef cattle, sheep, and goats) still relies on feeding standards developed in other countries, including the National Research Council (NRC) in the USA, the Agricultural and Food Research Council (AFRC) in the UK, the Institut National de la Recherche Agronomique (INRA) in France, the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia, and the Dutch Protein Evaluation System: DVE/OEB system (Indarsih, 2009; Baihaqi and Herman, 2012; Lestari et al., 2015). However, it is important to consider that the application of feeding standards from other countries may not be always suitable due to factors such as differences in nutritive value and feed ingredients, environmental conditions, and genetics and animal breeds (Salah et al., 2014). Genetically, as noted by the NRC (2000) and Chizzotti et al. (2008), Bos taurus breeds have 10% higher net energy for maintenance compared to Bos indicus breeds. Additionally, differences in environmental conditions and the nutritive values of feed between tropical and temperate regions will influence the energy and protein requirements of animals. For these reasons, the development of animal feeding standards that consider local conditions in Indonesia is essential.

Feeding standards generally consist of the nutrient requirements of animals and the chemical composition of feedstuffs. Nutrient requirements vary and are specific to each species and physiological stage of the animal. A feeding standard is expected to provide essential information for formulating rations and managing livestock nutrition efficiently and economically. Several methods have been employed to determine nutrient requirements. For example, the calorimetric method employs a respiration chamber to assess energy requirements at the maintenance level (Dong et al., 2015). An alternative method, the comparative slaughter technique, involves feeding experiments where animals are given different intake levels to establish their energy and protein needs (Chizzotti et al., 2008; Zhao et al., 2016). Nonetheless, these methods are quite expensive and require sophisticated research facilities. Another approach to determining animal nutrient requirements is the meta-analysis method, which compiles data from various independent feeding trials (Chizzotti et al., 2008; Salah et al., 2014; Oliveira, 2015; Jayanegara et al., 2017). Meta-analysis is particularly suitable for contexts like ours, where abundant data from cattle production studies are available for calculating energy and protein requirements. Although several Indonesian researchers have explored nutrient requirements using the meta-analysis method, none have applied this approach specifically to local cattle in Indonesia. However, for other species in Indonesia, such as sheep, energy and protein requirements have previously been determined using the meta-analysis approach (Jayanegara et al., 2017).

The purpose of this study was to determine the energy and protein requirements of cattle in Indonesia, both for maintenance and growth, using a meta-analysis approach. As this is the first study to assess nutrient requirements for cattle in Indonesia using the meta-analysis method, further sequential studies are necessary to obtain more accurate feed requirements for cattle in the region.

Materials and Methods

Database Development

Published articles from various journals containing feeding trial data were collected to construct the database. The feeding trials in these articles had to be conducted in Indonesia and contain specific parameters necessary for inclusion in the database. A thorough evaluation of the full-text articles was also performed to assess data sufficiency for database inclusion. To be included, an article needed to report, at a minimum, the initial body weight (BW0), average daily gain (ADG), dry matter intake (DMI) of the cattle, and the chemical composition of the ration used (at least crude protein content).

Articles were searched using the keyword "cattle" across various Indonesian journal websites related to animal science. The journals searched included *Agripet*, *Agromedia*, *Animal Production*, *Buletin Makanan Ternak*, *Buletin Peternakan*, *Caraka Tani: Journal of Sustainable Agriculture*, *Journal of Indonesian Tropical Animal Agriculture*, *Jurnal Ilmiah Mahasiswa Pertanian Unsyiah*, *Jurnal Ilmiah Peternakan Terpadu*, *Jurnal Ilmu dan Teknologi Peternakan*

Tropis, *Jurnal Ilmu Pertanian Indonesia*, *Jurnal Ilmu Produksi dan Teknologi Hasil Peternakan*, *Jurnal Ilmu Ternak dan Veteriner*, *Jurnal Ilmu-Ilmu Peternakan*, *Jurnal Peternakan Integratif*, *Jurnal Zootek*, *Media Peternakan*, *Peternakan Tropika*, and *Sains Peternakan*.

A total of 57 articles, comprising 191 data points representing different dietary treatments, were integrated into the database. The articles were screened based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocols, as shown in Figure 1. (Aditia et al., 2013; Adiwinarti et al., 2010; Afzalani et al., 2017; Agus et al., 2005; Ariwibawa et al., 2015; Astuti et al., 2009; 2015; Bain et al., 2016; Bata et al., 2016; Carvalho et al., 2010; Fauzyah et al., 2017; Hartati et al., 2009; 2012; Haryanto et al., 2012; 2016; Ibrahim et al., 2013; Khasrad and Rusdimansyah, 2012; Lani et al., 2015; Lestari et al., 2011; Mahyuddin et al., 2016; Mahyuddin and Winugroho, 2010; Mahyuddin, 2001; Mahyuddin, 2002; Manurung, 1996; Mualimin et al., 2015; Mualimin et al., 2015; Ngadiyono, 1996; Ngadiyono et al. 2001; Nusi et al., 2011; Prayitno et al., 2014; Priyanto et al., 2015; Purnomoadi et al., 2008; Purwanti et al., 2014; Rab et al., 2016; Rab et al., 2016; Ratnawati and Aryogi, 2016; Rauf et al., 2015; Rianto et al., 2005; Riswandi et al., 2015; Riyanto et al., 2017; Saepudin et al., 2016; Santosa et al., 2012; Sari et al., 2016; Setiawan and Nuraini, 2016; Sihombing et al., 2015; Soeprapto, 2011; Suharti et al., 2009; Suherman et al., 2018; Suryani et al., 2014; Tahuk and Dethan, 2010; Baliarti, 2018; Umar et al., 2015; Valentina et al., 2018; Wiryawan et al. 2017; Yakin et al., 2013; Yantika et al. 2016).

Different cattle breeds (Aceh, Bali, Madura, Peranakan Ongole, Sumba Ongole, and Local) and sexes (male and female) were specified in the database. Initially, the database also included Pesisir, Brahman X, Simmental X, Simmental Ongole, and Limosin Ongole breeds; however, these were combined under the category "Local" due to the insufficient number of articles available (Puastuti et al., 2010; Yulistiani et al., 2011; Yulistiani et al., 2013).

The parameters considered in the analysis included dry matter intake (DMI), crude protein intake (CPI), total digestible nutrient intake (TDNI), and average daily gain (ADG). To account for differences in cattle body weight, intake and ADG values were adjusted based on metabolic body weight (MBW, calculated as $BW^{0.75}$). All data for each parameter were converted into uniform measurement units to facilitate direct comparison and analysis. A summary of the database used in the meta-analysis is provided in Table 1.

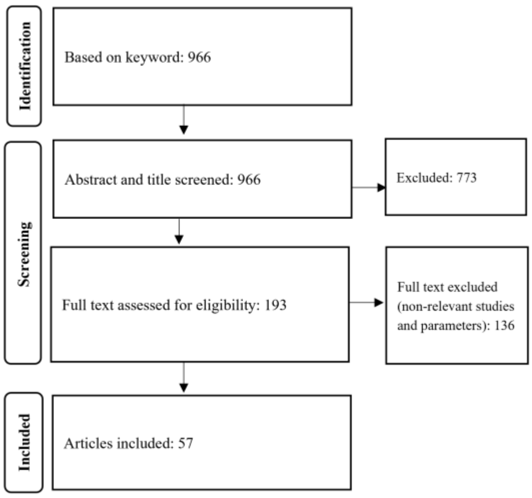

Figure 1. PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) flow chart

Table 1. Descriptive statistics of database used in meta-analysis

Parameter	Unit	Breed	N	Mean	SD	Min	Max
DMI	kg/d	Aceh	16	7.01	2.58	3.89	10.47
		Bali	62	5.12	1.61	0.49	8.18
		Madura	19	5.64	1.20	3.37	7.90
		Peranakan Ongole	54	5.79	2.92	1.88	11.50
		Sumba Ongole	16	8.46	1.84	6.34	11.74
		Local	24	8.31	3.36	2.83	13.68
CPI	kg/d	Aceh	16	0.67	0.31	0.33	1.19
		Bali	44	0.66	0.27	0.06	1.24
		Madura	19	0.73	0.29	0.31	1.30
		Peranakan Ongole	39	0.74	0.23	0.38	1.35
		Sumba Ongole	12	1.10	0.46	0.73	1.98
		Local	20	2.05	2.27	0.38	7.87
EEI	kg/d	Aceh	16	0.68	0.89	0.04	2.45
		Bali	32	0.21	0.16	0.01	0.63
		Madura	19	0.14	0.10	0.06	0.41
		Peranakan Ongole	34	0.92	1.42	0.02	4.17
		Sumba Ongole	7	1.30	1.31	0.27	3.55
		Local	20	0.35	0.22	0.03	0.87
CFI	kg/d	Aceh	16	1.38	0.59	0.79	3.25
		Bali	37	3.77	5.39	0.06	17.42
		Madura	19	1.27	0.36	0.43	1.80
		Peranakan Ongole	40	2.66	4.76	0.22	18.12
		Sumba Ongole	13	3.41	2.29	1.52	8.27
		Local	23	2.19	1.38	0.72	6.27
NDFI	kg/d	Aceh	na	na	na	na	na
		Bali	7	2.65	1.64	0.81	4.31
		Madura	na	na	na	na	na
		Peranakan Ongole	2	6.77	0.05	6.74	6.80
		Sumba Ongole	na	na	na	na	na
		Local	na	na	na	na	na
ADFI	kg/d	Aceh	na	na	na	na	na
		Bali	11	1.50	1.02	0.48	3.13
		Madura	na	na	na	na	na
		Peranakan Ongole	na	na	na	na	na
		Sumba Ongole	na	na	na	na	na
		Local	na	na	na	na	na
TDNI	kg/d	Aceh	8	2.88	0.13	2.75	3.08
		Bali	33	3.29	1.12	1.14	4.65
		Madura	15	3.81	1.01	2.32	5.40
		Peranakan Ongole	32	3.39	1.79	0.84	9.94
		Sumba Ongole	5	6.06	1.61	4.46	7.79
		Local	16	5.37	2.55	1.20	10.54
ADG	kg/d	Aceh	16	0.42	0.13	0.15	0.66
		Bali	62	0.48	0.18	0.10	0.92
		Madura	19	0.56	0.18	0.26	0.81
		Peranakan Ongole	54	0.66	0.29	0.14	1.30
		Sumba Ongole	16	1.12	0.21	0.82	1.57
		Local	24	0.78	0.32	0.22	1.53
G:F	%	Aceh	16	6.96	3.56	1.47	14.70
		Bali	62	10.32	4.75	1.63	28.16
		Madura	19	10.05	2.85	5.36	14.18
		Peranakan Ongole	54	13.05	6.95	3.56	33.88
		Sumba Ongole	16	13.70	3.43	8.64	19.87
		Local	24	9.97	3.53	3.23	15.64
DMD	%	Aceh	na	na	na	na	na

Parameter	Unit	Breed	N	Mean	SD	Min	Max
		Bali	11	68.44	9.87	53.51	79.75
		Madura	8	77.20	8.17	64.60	83.60
		Peranakan Ongole	12	60.18	8.81	42.27	70.77
		Sumba Ongole	na	na	na	na	na
		Local	4	55.47	9.81	45.75	68.57
NH_3	mmol/L	Aceh	na	na	na	na	na
		Bali	na	na	na	na	na
		Madura	4	5.03	2.09	3.10	7.50
		Peranakan Ongole	na	na	na	na	na
		Sumba Ongole	na	na	na	na	na
		Local	na	na	na	na	na
Total VFA	mmol/L	Aceh	na	na	na	na	na
		Bali	na	na	na	na	na
		Madura	4	63.00	11.23	52.40	72.80
		Peranakan Ongole	na	na	na	na	na
		Sumba Ongole	na	na	na	na	na
		Local	na	na	na	na	na

Notes: N = number of data, SD = standard deviation, DMI = dry matter intake, CPI = crude protein intake, EEI = ether extract intake, CFI = crude fiber intake, TDNI = total digestible nutrient intake, ADG = average daily gain, G:F = gain 0.75 to feed, DMD = dry matter digestibility, MBW = metabolic body weight (BW), na = data not available.

Data Analysis

A fixed-effects model was employed for the meta-analysis, with each study treated as a fixed effect. No weighting procedure was used in this analysis. The dependent variable was adjusted by adding the predicted values to their corresponding residuals, allowing for a two-dimensional graphical representation of data from multi-dimensional studies (St-Pierre, 2001). The relationships between ADG and DMI, CPI, and TDNI were individually regressed to determine the maintenance and growth requirements for dry matter, energy, and protein. The intercept (where ADG = 0 g/kg MBW/d) indicated the maintenance requirement, while the slope (nutrient intake required per unit of ADG) represented the growth requirement. The goodness-of-fit of the model was assessed using the P-value and the coefficient of determination (R^2). All statistical analyses were performed using Minitab 17.

Results and Discussion

Dry Matter Intake of Cattle

Regression analysis between ADG and DMI revealed a positive linear relationship (P<0.001; Figure 2). Recommendations for DMI were generally classified as shown in Table 2. DMI, as a critical component of feed intake, plays a major role in determining livestock performance. Several factors influence feed intake in ruminants, including physiological, environmental, management, ^ dietary factors. Physiological factors, such as body composition, sex, age, frame size, & physiological state, can significantly impact feed intake. Environmental factors, including day length and thermal effects, also influence feed intake. Additionally, management & dietary factors, such as feeding systems, physical and chemical properties of the feed, hormones, and feed additives, play a role in modulating feed intake (NRC, 2007).

Predicting DMI in ruminants has been attempted using several factors, with body weight (BW) being a reliable predictor. According to Jayanegara et al. (2017) estimated DMI from BW, achieving an R^2 value of 0.83. Feed intake is known to be related to maintenance requirements, whereas body weight increases, the maintenance requirement per unit of body weight decreases. Consequently, the relationship between feed intake and body weight also decreases proportionally (Riaz et al., 2014).

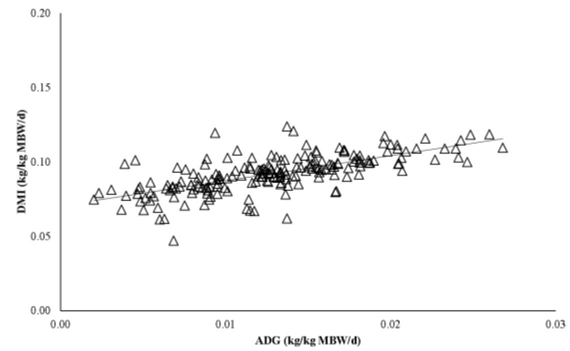

Figure 2. Relationship between dry matter intake (DMI, kg/kg MBW/d) and average daily gain (ADG, kg/kg MBW/d). DMI (kg/kg MBW/d) = 0.071 + 1.857 ADG (kg/kg MBW/d) (N= 191; P<0.001; R^2= 0.931). All interactions between breed, sex, and ADG on DMI were insignificant

This study observed a similar trend: cattle with a BW of 100 kg required DMI at 2.24% of BW, which decreased to 1.49% of BW when BW reached 500 kg. For example, using the equation presented in Figure 1, cattle with a BW of 300 kg and an ADG of 1 kg would require a DMI of 6.03 kg/d (Table 2). DMI is strongly influenced by ADG, environmental conditions, management practices, and other physiological factors. In our meta-analysis, the percentage of DMI for the cattle breeds studied ranged from 2.01-2.94% of BW for cattle with a BW of 300 kg and ADG ranging from 0.5-2.0 kg. In related research, Jayanegara et al. (2017) conducted a meta-analysis on local sheep and concluded that the DMI requirement for sheep was 3.64% of BW.

The NRC (2000) predicted DMI using a new equation, estimating that cattle with a mean BW of 410 kg would require approximately 9.0 kg/day of DMI with a dietary NE_m of 1.6 Mcal/kg. In our meta-analysis, DMI intake for cattle with a BW of 400 kg ranged from 7.26 to 10.05 kg/day, with ADG ranging from 0.5 to 1.0 kg/day. Block et al. (2010) conducted research to assess the accuracy and precision of the NRC's energy requirement and DMI equations, concluding that these equations lacked accuracy and precision when applied to wintering beef cattle in Western Canada. Additionally, Boval et al. (2015), using a meta-analysis approach, indicated a direct relationship between ADG and digestible DMI (ADG = −1.63 + 0.42 DDMI; R^2 = 0.93)).

Protein Requirement of Cattle

The NRC standard for nutrient requirements of cattle production has been widely used globally for a long time. However, this standard was developed by calculating requirements for uniform cattle without considering environmental conditions and other variables that affect cattle production.

Table 2. Recommended dry matter, energy (total digestible nutrient, TDN) and crude protein (CP) intake for Aceh, Bali, Madura, Peranakan Ongole, Sumba Ongole, and Local cattle in Indonesia

BW (Kg)	ADG (Kg)	Aceh (Kg/d)			Bali (Kg/d)			Madura (Kg/d)			Peranakan Ongole (Kg/d)			Sumba Ongole (Kg/d)			Local (Kg/d)		
		DM	CP	TDN	DM	CP	TDN	DM	CP	TDN	DM	CP	TDN	DM	CP	TDN	DM	CP	TDN
100	0	2.24	0.17	0.73	2.24	0.22	1.59	2.24	0.04	0.83	2.24	0.32	2.17	2.24	0.23	1.02	2.24	0.10	1.58
	0.5	3.17	0.24	2.98	3.17	0.41	2.43	3.17	0.76	3.33	3.17	0.40	2.42	3.17	0.39	2.52	3.17	0.69	2.45
	1	4.10	0.30	5.22	4.10	0.60	3.27	4.10	1.47	5.84	4.10	0.47	2.66	4.10	0.55	4.03	4.10	1.27	3.33
	1.5	5.03	0.36	7.46	5.03	0.80	4.11	5.03	2.18	8.34	5.03	0.54	2.91	5.03	0.71	5.53	5.03	1.86	4.20
	2	5.95	0.42	9.70	5.95	0.99	4.95	5.95	2.89	10.85	5.95	0.62	3.16	5.95	0.87	7.04	5.95	2.44	5.08
200	0	3.77	0.29	1.23	3.77	0.36	2.68	3.77	0.07	1.39	3.77	0.54	3.65	3.77	0.38	1.71	3.77	0.17	2.65
	0.5	4.70	0.35	3.48	4.70	0.56	3.52	4.70	0.79	3.89	4.70	0.61	3.90	4.70	0.54	3.21	4.70	0.76	3.53
	1	5.62	0.42	5.72	5.62	0.75	4.36	5.62	1.50	6.40	5.62	0.69	4.14	5.62	0.70	4.72	5.62	1.34	4.40
	1.5	6.55	0.48	7.96	6.55	0.95	5.20	6.55	2.21	8.90	6.55	0.76	4.39	6.55	0.86	6.22	6.55	1.93	5.28
	2	7.48	0.54	10.20	7.48	1.14	6.04	7.48	2.92	11.41	7.48	0.84	4.64	7.48	1.02	7.73	7.48	2.51	6.15
300	0	5.11	0.39	1.67	5.11	0.49	3.63	5.11	0.10	1.88	5.11	0.73	4.95	5.11	0.52	2.31	5.11	0.24	3.60
	0.5	6.03	0.46	3.91	6.03	0.68	4.47	6.03	0.81	4.39	6.03	0.81	5.20	6.03	0.68	3.82	6.03	0.82	4.47
	1	6.96	0.52	6.16	6.96	0.88	5.31	6.96	1.53	6.89	6.96	0.88	5.44	6.96	0.84	5.32	6.96	1.41	5.35
	1.5	7.89	0.58	8.40	7.89	1.07	6.15	7.89	2.24	9.40	7.89	0.96	5.69	7.89	1.00	6.83	7.89	1.99	6.22
	2	8.82	0.64	10.64	8.82	1.27	6.99	8.82	2.95	11.90	8.82	1.03	5.93	8.82	1.16	8.33	8.82	2.58	7.10
400	0	6.34	0.49	2.08	6.34	0.61	4.51	6.34	0.13	2.33	6.34	0.91	6.14	6.34	0.64	2.87	6.34	0.29	4.46
	0.5	7.26	0.55	4.32	7.26	0.80	5.35	7.26	0.84	4.84	7.26	0.98	6.39	7.26	0.80	4.38	7.26	0.88	5.34
	1	8.19	0.61	6.56	8.19	1.00	6.19	8.19	1.55	7.34	8.19	1.06	6.63	8.19	0.96	5.88	8.19	1.46	6.21
	1.5	9.12	0.68	8.80	9.12	1.19	7.03	9.12	2.26	9.85	9.12	1.13	6.88	9.12	1.12	7.39	9.12	2.05	7.09
	2	10.05	0.74	11.04	10.05	1.39	7.87	10.05	2.97	12.35	10.05	1.21	7.13	10.05	1.28	8.89	10.05	2.63	7.96
500	0	7.49	0.58	2.45	7.49	0.72	5.33	7.49	0.15	2.76	7.49	1.07	7.26	7.49	0.76	3.39	7.49	0.35	5.28
	0.5	8.42	0.64	4.70	8.42	0.91	6.17	8.42	0.86	5.26	8.42	1.15	7.51	8.42	0.92	4.90	8.42	0.93	6.15
	1	9.35	0.70	6.94	9.35	1.11	7.01	9.35	1.57	7.77	9.35	1.22	7.75	9.35	1.08	6.40	9.35	1.52	7.03
	1.5	10.27	0.77	9.18	10.27	1.30	7.85	10.27	2.29	10.27	10.27	1.30	8.00	10.27	1.24	7.91	10.27	2.10	7.90
	2	11.20	0.83	11.42	11.20	1.50	8.69	11.20	3.00	12.78	11.20	1.37	8.24	11.20	1.40	9.41	11.20	2.69	8.78

The availability of energy and protein in feed is highly dependent on the quality of feed sources, which is influenced by factors such as soil condition, harvest time, and other variables that are not accounted for by NRC methods. Research conducted by Fox et al. (1992), using the Cornell Net Carbohydrate and Protein System (CNCPS), indicated that, based on DMI and metabolizable protein, the CNCPS had a 12% lower standard error and 1.6% less bias compared to the NRC system. The CNCPS model for predicting ME and protein requirements of cattle has also been reported by Russell et al. (1992) and Sniffen et al. (1992). Additionally, Samadi and Yu (2011) applied the CNCPS to predict energy using dry and moist soybean as models.

Estimating protein degradation in the rumen is crucial for evaluating the protein requirements of ruminant animals. The older system, which relied on crude protein (CP) content, was less accurate compared to the metabolizable protein (MP) system (Owens et al., 2014; Van Amburgh et al., 2015). The CP system does not differentiate between the protein needs of microbes and those of the host animal (Das et al., 2014). In contrast, the MP system offers several advantages for estimating protein requirements in ruminant animals: (1) it allows for the optimization of carbohydrate digestion and microbial protein synthesis by calculating the rumen degradable protein (RDP) needed by rumen microbes, (2) it ensures that the minimum intake of rumen undegradable protein (RUP) is utilized to meet the requirements of the host animal for growth, maintenance, reproduction, and health, and (3) it enables the use of minimum dietary CP (including MP and amino acids) to achieve the desired production levels in the host animal (Das et al., 2014).

Figure 3 illustrates the relationship between CPI (kg/kg MBW/d) and ADG (kg/kg MBW/d) for different breeds of cattle in Indonesia, with coefficients of determination (R^2) of 0.97, 0.93, 0.43, 0.87, 0.96, and 0.94 for Aceh, Bali, Madura, Peranakan Ongole (PO), Sumba Ongole (SO), and local breeds, respectively. The CP requirements for Indonesian cattle breeds obtained through a meta-analysis approach are presented in Table 2. The recommendations for CP requirements are categorized by body weight (BW) ranging from 100 to 500 kg and ADG from 0 to 1.5 kg. There were slight differences in CP requirements among the breeds in Indonesia.

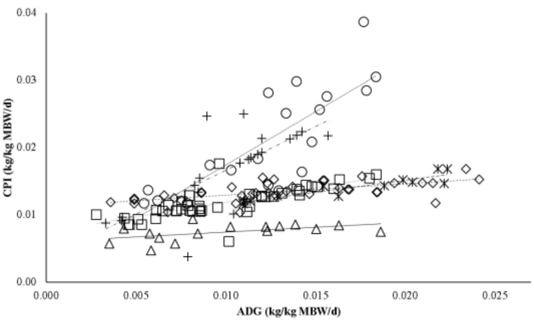

Figure 3. Relationship between crude protein intake (CPI, kg/kg MBW/d) and average daily gain (ADG, kg/kg MBW/d) of Aceh (-Δ-), Bali (-□-), Madura (-○-), PO (-◇-), SO (-*-) and Local (-+-) Cattle breeds.

Aceh breed	:	CPI (kg/kg MBW/d) = 0.0055 + 0.1260 ADG (kg/kg MBW/d) (N= 16; P<0.001; R^2= 0.979)
Bali breed	:	CPI (kg/kg MBW/d) = 0.0068 + 0.3890 ADG (kg/kg MBW/d) (N= 44; P<0.001; R^2= 0.934)
Madura breed	:	CPI (kg/kg MBW/d) = 0.0014 + 1.4240 ADG (kg/kg MBW/d) (N= 19; P= 0.77; R^2= 0.433)
PO breed	:	CPI (kg/kg MBW/d) = 0.0102 + 0.1490 ADG (kg/kg MBW/d) (N= 39; P<0.001; R^2= 0.872)
SO breed	:	CPI (kg/kg MBW/d) = 0.0072 + 0.3200 ADG (kg/kg MBW/d) (N= 12; P= 0.125; R^2= 0.968)
Local breed	:	CPI (kg/kg MBW/d) = 0.0033 + 1.1700 ADG (kg/kg MBW/d) (N= 20; P= 0.65; R^2= 0.939)

A study conducted by Tangjitwattanachai and Sommart (2009) evaluated the protein requirements for maintenance and gain of Thai native cattle using a meta-analysis approach, based on a database of 130 observations from 12 feeding trials. The study concluded that the protein required for gain (CPg) at 100 g/kg $BW^{0.75}$ was 38, 56, and 59 g CP/kg $BW^{0.75}$/d for Thai native, Brahman, and Brahman crossbred cattle, respectively. The results also indicated that the maintenance protein requirement for Brahman cattle was approximately 10.14% and 17% lower than that for Thai native and Brahman crossbred cattle, respectively.

Based on our study, as shown in Figure 2, the crude protein (CP) requirements for a 300 kg body weight (BW) animal with an average daily gain (ADG) of 1 kg/day were 0.52, 0.88, 1.58, 0.88, 0.84, and 1.44 kg/day for Aceh, Bali, Madura, Peranakan Ongole (PO), Sumba Ongole (SO), and local breeds, respectively. According to the NRC (2000), several studies have estimated that the metabolizable protein (MP) requirement for cattle is 3.8 g MP/kg $BW^{0.75}$ for maintenance, which, when converted to CP, equates to 658 g CP/day. Wilkerson et al. (1993) reported that the metabolizable amino acid requirements as a percentage of MP for a 253 kg animal gaining 0.49 kg/day were 3.0% for methionine, 5.8% for total sulfur amino acids, 8.0% for lysine, 1.0% for tryptophan, 5.2% for threonine, 5.7% for valine, 5.6% for isoleucine, 6.9% for leucine, 3.9% for phenylalanine, and 1.6% for histidine. A study by Salah et al. (2014), which used meta-analysis data from tropical climates, concluded that the digestible CP requirement for cattle was 2.81 g/kg $BW^{0.75}$. Our study indicated that the Madura and local breeds required more CP (kg/day) compared to the other breeds.

Energy Requirement of Cattle

In cattle production, energy is primarily referred to as digestible energy, which includes net energy for maintenance (NEm), gain (NEg), lactation (NEl), and total digestible nutrients (TDN). Cattle first use energy to meet their maintenance requirements before it is allocated for other purposes, such as growth, production, and lactation. The energy requirements of cattle are influenced by several factors, including the production stage, animal size, and expected performance. In this meta-analysis study, energy intake was primarily expressed in the form of TDN. Energy requirements for animals can also be estimated based on their chemical composition, as reported by Samadi et al. (2013). Jayanegara et al. (2017) noted, through a meta-analysis approach, that TDN is not ideal for measuring energy and suggested that it should be replaced with other systems such as metabolizable energy (ME) or net energy (NE) systems.

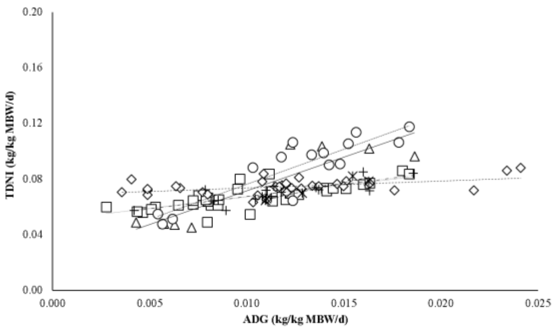

Figure 4. Relationship between total digestible nutrient intake (TDNI, kg/kg MBW/d) and average daily gain (ADG, kg/ kg MBW/d) of Aceh (-Δ-), Bali (-□-), Madura (-○-), PO (-◇-), SO (-*) and Local (-+-) Cattle breeds.

Aceh breed : TDNI (kg/kg MBW/d) = 0.0232 + 4.4840 ADG (kg/kg MBW/d) (N= 8; P= 0.093; R^2= 0.734)

Bali breed : TDNI (kg/kg MBW/d) = 0.0504 + 1.6800 ADG (kg/kg MBW/d) (N= 33; P<0.001; R^2= 0.951)

Madura breed : TDNI (kg/kg MBW/d) = 0.0261 + 5.0100 ADG (kg/kg MBW/d) (N= 15; P= 0.082; R^2= 0.618)

PO breed : TDNI (kg/kg MBW/d) = 0.0687 + 0.4930 ADG (kg/kg MBW/d) (N= 32; P<0.001; R^2= 0.919)

SO breed : TDNI (kg/kg MBW/d) = 0.0321 + 3.0100 ADG (kg/kg MBW/d) (N= 5; P= 0.2421; R^2= 0.921)

Local breed : TDNI (kg/kg MBW/d) = 0.0499 + 1.7500 ADG (kg/kg MBW/d) (N= 16; P= 0.133; R^2= 0.915)

The relationship between total digestible nutrient intake (TDNI, kg/kg MBW/d) and average daily gain (ADG, kg/kg MBW/d) across various cattle breeds in Indonesia is illustrated in Figure 3. The correlation is relatively strong, with R^2 values of 0.73, 0.95, 0.61, 0.92, 0.92, and 0.91 for Aceh, Bali, Madura, PO, SO, and local breeds, respectively. The TDN requirements for Indonesian cattle breeds, as determined through a meta-analysis, are presented in Table 2. Recommendations for TDN intake were estimated based on BW ranging from 100 to 500 kg and ADG from 0 to 1.5 kg. There were slight variations in TDN requirements between breeds in Indonesia, influenced by factors such as production stage, animal size, and expected performance. Valente et al. (2013) noted that energy requirements vary with animal activity, with grazing cattle needing more energy than feedlot cattle due to increased physical exertion.

The recommended TDN requirements for various cattle breeds in Indonesia, based on a meta-analysis, are presented in Table 2. For instance, the TDN requirements for cattle with a BW of 300 kg and an ADG of 1 kg/day were 6.16, 5.13, 6.89, 5.44, 5.32, and 5.35 kg/day for Aceh, Bali, Madura, PO, SO, and local breeds, respectively. Paul et al. (2004) reported a predicted TDNI requirement of 6.39 kg/day for lactating cattle, which is slightly similar to the results of our meta-analysis. In this study, the maintenance requirement for lactating cattle was 4.18 kg/day for 500 kg cattle, with an additional 1.78 kg/day needed for body weight gain. Block et al. (2001) reported that the TDNI for cattle to achieve an ADG of 2.14 lb (0.97 kg) was 14.68 lb/day (6.66 kg/day). However, Block et al. (2006) indicated that the NRC model lacks accuracy because its requirements are focused on feedlot evaluations and do not consider other factors, such as environmental conditions.

Conclusions

This meta-analysis revealed that each cattle breed in Indonesia has its particular TDN and CP requirements. The energy and protein need for both maintenance (CP_m and TDN_m) and gain (CP_g and TDN_g) differ across breeds. Specifically, the Madura breed requires less CP_m, while the Aceh breed has lower TDN_m requirements for maintenance. In contrast, the PO breed requires more CP_m and TDN_m requirements compared to other breeds. For gain, the Aceh and PO breeds need less CP_g and TDN_g, respectively, whereas the Madura breed requires higher amounts of both CP_g and TDN_g. Further research on the energy and protein requirements of Indonesian cattle is necessary to validate these findings.

Acknowledgement

This study was supported by Universitas Syiah Kuala grant under Professorship scheme in 2018. The authors thank the Institute for Research and Community Services (LPPM) of Universitas Syiah Kuala for managing the financial support necessary to conduct this research.

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