Determination of Energy and Protein Requirements of Sheep in Indonesia using a Meta-analytical Approach

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ABSTRACT

The objective of this study was to determine energy and protein requirements, for both maintenance and gain, of sheep in Indonesia by using a meta-analysis method. A database was developed from various in vivo experiments involving sheep as the experimental animals in which energy intake, protein intake and average daily weight gain (ADG) were reported. A total of 38 articles consisting of 137 data points were integrated into the database. Different breeds (Priangan, fat-tailed and local) and sexes (male and female) were specified in the database. Maintenance and gain requirements of dry matter, energy and protein were determined by regressing ADG with dry matter intake (DMI), total digestible nutrient intake (TDNI) and crude protein intake (CPI), respectively. An intercept (where ADG= 0 g/kg MBW/d) and a slope (required nutrient intake per unit ADG) were taken as maintenance and gain requirements, respectively. Results revealed that all sheep breeds had similar energy requirement for maintenance (TDN\textsubscript{m}). Energy requirement for gain (TDN\textsubscript{g}) of Priangan breed was lower than other breeds; the breed required 0.860 g TDN for 1 g ADG. Fat-tailed and local breeds required 1.22 and 2.75 g TDN for 1 g ADG, respectively. All breeds also revealed relatively similar protein requirement for maintenance (CP\textsubscript{m}), i.e. 6.27-6.47 g/kg MBW/d. Priangan breed required less CP for 1 g ADG (CP\textsubscript{g}), i.e. 0.295 g. Requirements of CP\textsubscript{g} for fat-tailed and local breeds were 0.336 and 0.497 g/g ADG, respectively. It was concluded that each sheep breed in Indonesia had specific TDN and CP requirements for gain, but similar requirements for maintenance.

Keywords: nutrient requirement, energy, protein, sheep, meta-analysis

Penelitian ini bertujuan untuk menentukan kebutuhan energi dan protein domba di Indonesia menggunakan metode meta-analisis. Berbagai eksperimen pakan/nutrisi yang menggunakan domba dan melaporkan peubah konsumsi energi, konsumsi protein dan pertambahan bobot badan (PBB) ditabulasi dalam suatu database. Sebanyak 38 artikel yang terdiri atas 137 data diintegrasikan pada database tersebut. Bangsa domba yang berbeda (Priangan, ekor gemuk dan lokal) dan jenis kelamin (jantan dan betina) juga diinformasikan. Kebutuhan hidup pokok dan pertumbuhan untuk bahan kering (BK), energi (TDN) dan protein (PK) didapatkan melalui regresi antara PBB dengan konsumsi BK, konsumsi TDN dan konsumsi PK. Kebutuhan hidup pokok didapatkan melalui nilai intersep regresi (ketika PBB= 0 g/kg bobot badan metabolik [BBM]/hari) sedangkan kebutuhan pertumbuhan adalah nilai kemiringan (konsumsi per unit PBB) dari persamaan regresi. Hasil menunjukkan bahwa semua bangsa domba yang diamati memiliki kebutuhan energi untuk hidup pokok (TDN\textsubscript{m}) yang sama. Kebutuhan energi untuk pertumbuhan (TDN\textsubscript{g}) dari domba priangan lebih rendah dibandingkan dengan bangsa domba lainnya; domba priangan membantu 0,860 g TDN untuk setiap 1 g PBB. Domba ekor gemuk dan domba lokal membutuhkan 1,22 dan 2,75 g TDN untuk setiap 1 g PBB. Semua bangsa domba tersebut memiliki kebutuhan protein untuk hidup pokok yang sama (CP\textsubscript{m}), yakni sekitar 6,27-6,47 g/kg BBM/hari. Kebutuhan protein untuk pertumbuhan (CP\textsubscript{g}) dari domba priangan, domba ekor gemuk dan domba lokal adalah 0,295, 0,336 dan 0,497 g/g PBB. Disimpulkan bahwa setiap bangsa domba di Indonesia memiliki kebutuhan energi dan protein untuk pertumbuhan yang spesifik, namun memiliki kebutuhan hidup pokok yang sama.

Kata kunci: kebutuhan nutrisi, energi, protein, domba, meta-analysis

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INTRODUCTION

Current practice of ration formulation for various livestock in Indonesia, either ruminants (beef cattle, dairy cattle, sheep and goat) or monogastrics (poultry and swine), follows feeding standards developed in other countries, particularly National Research Council (NRC) standard of the USA (Indarsih, 2009; Baihaqi & Herman, 2012; Lestari et al., 2015). Although other feeding standards such as from UK (AFRC), France (INRA), Australia (CSIRO) and Dutch (VEM-DVE) are available, they are rarely used in the country. However, using standard from other country may not be suitable because of a number of considerable differences such as (1) feed ingredient and nutritional quality, (2) environmental condition, and (3) animal breed and genetics (Salah et al., 2014). It is well accepted that different feed and environmental condition (tropics vs temperate), for instance, affect nutrient utilization and partition, animal growth, body composition and, hence, energy and protein requirements of animals. Further, regarding animal breed and genetics, Bos indicus breeds have 10% less net energy for maintenance requirement than Bos taurus breeds (NRC, 2000; Chizzotti et al., 2008). Thus, it is apparent that developing our own feeding standard is essential for animals under local condition in Indonesia.

A feeding standard generally has two parts, i.e. (1) nutrient requirement of animals, specific per species and at different physiological stages and (2) chemical composition of feedstuffs. The feeding standard has to, in turn, contribute to optimal diet formulation and allows proper nutritional management in an efficient, technical and economical way. Methods for determining energy and protein requirements of animals are mostly based on (1) calorimetric method and (2) comparative slaughter method. The calorimetric method uses respiration chamber to measure gas exchange, heat production during fasting, and loss of energy through urine and methane at maintenance level of animal feeding (Dong et al., 2015). The comparative slaughter method employs feeding trials in which animals are fed at two or more levels of intake, and one of them is at maintenance level. Metabolizable energy (ME) intake and retained energy (RE) as the change in body energy content of animals are measured through this procedure. The slope of linear regression between RE and ME intake indicates efficiency of ME utilization or ME for gain (Chizzotti et al., 2007; Zhao et al., 2016). Both methods require relatively sophisticated research facilities and financial resources to perform the experiments in which these are among the main obstacles in Indonesia. Further, it may take quite long time to generate data from different experiments so that the energy and protein requirements are accurate and reliable.

A more recent method of determining nutrient requirements of animals is meta-analysis study using data from feeding trials across various independent experiments (Chizzotti et al., 2008; Salah et al., 2014; Oliveira, 2015). Although meta-analysis studies have been conducted by Indonesian researchers (Palupi et al., 2012; Jayanegara et al., 2014), the method has not been applied to the determination of nutrient requirement of animals in Indonesia. This method seems suitable for us since significant amount of data have already been generated on feed or nutrient intake, nutrient digestibility and production performance of animals. To date, determination of nutrient requirement on sheep by using a meta-analytical approach worldwide is scarce (Salah et al., 2014). The objective of this study was, therefore, to determine energy and protein requirements, for both maintenance and gain, of sheep in Indonesia by using a meta-analytical approach. Since this is the first study of such objective in Indonesia, determination of nutrient requirement of other livestock species are subjected to further sequential studies provided that the results obtained are proved to be accurate and reliable through further studies.

MATERIALS AND METHODS

Database Development

A database was constructed from published articles on feeding trials involving sheep as the experimental animals and in which the experiments were performed in Indonesia. The articles were obtained from various Indonesian journals related to animal science, i.e. (1) Media Peternakan, (2) Jurnal Pengembangan Peternakan Tropis, (3) Buletin Peternakan, (4) Jurnal Ilmu Ternak dan Veteriner, (5) Jurnal Peternakan Integratif, (6) Jurnal Agripet, (7) Jurnal Ilmu-ilmu Peternakan, and (8) Jurnal Ilmu Ternak. In each journal website, literature search was conducted with a keyword “sheep”. All full text articles found were evaluated for their suitability to be included in the database. Minimum criteria for an article to be included in the database were that initial body weight (BW,), average daily gain (ADG), dry matter intake (DMI) of sheep, and chemical composition of the ration used (at least crude protein content) were reported.

A total of 38 articles consisting of 137 data points (represented different dietary treatments) were integrated into the database (Mathius et al., 1996; 1997; 1998; Thalib et al., 1996; 2010; Lubis et al., 1998; 2002; Mahyuddin, 2001; Duldjaman, 2004; Tarmidi, 2004; Adawiyah et al., 2006; Puastuti et al., 2006; Uhi, 2006; Supriatni & Haryanto, 2007; Wiryawan et al., 2007; Sudanman et al., 2008; Supriyati, 2008; Tanuwiria & Ayuningsih, 2008; Thalib & Widiawati, 2008; Zain, 2009; Hartutik et al., 2010; Hernaman et al., 2011; Widiyanto et al., 2011; 2012; Rimbawanto et al., 2012; Ginting et al., 2013; Ketaren et al., 2013; Sitanggang et al., 2013; Braymana et al., 2014; Ekawati et al., 2014; Khotijah et al., 2014; Nababan et al., 2014; Ndur et al., 2014; Wulandari et al., 2014; Aqbari et al., 2015; Simanjuntak et al., 2015; Tiven et al., 2015; Wati et al., 2015). Different breeds (Priangan, fat-tailed and local) and sexes (male and female) were specified in the database. Initially there was also Sumatra sheep but the data were excluded due to scarcity of articles available (Puastuti et al., 2010; Yulistiani et al., 2011; 2013). Parameters included were dry matter intake (DMI), crude protein intake (CPI),
ether extract intake (EEI), crude fiber intake (CFI), neutral detergent fiber intake (NDFI), acid detergent fiber intake (ADFI), total digestible nutrient intake (TDNI), average daily gain (ADG), gain to feed ratio (G:F), dry matter digestibility (DMD), rumen ammonia (NH<sub>3</sub>) concentration and total volatile fatty acid (VFA) concentration. Parameters related to intake and ADG were expressed in relation to metabolic body weight (MBW, i.e BW<sup>0.75</sup>) to account for variation due to different body weight of sheep. Data within a parameter were transformed into a similar measurement unit in order to allow direct analysis. Summary of the database used in the meta-analysis is presented in Table 1.

**Data Analysis**

Meta-analysis was performed by using a mixed model statistics (St-Pierre, 2001; Sauvant et al., 2008) in which different studies were considered as random effects whereas different breeds, sexes and nutrient intake were considered as fixed effects. Interaction between breed×sex, breed×intake, sex×intake and breed×sex×intake on dependent variables were initially tested. Any insignificant interactions were then removed from the statistical model. Significance of an effect was stated at P<0.05. Qualitative information such as study, breed and sex were stated in the class statement.

| Parameter | Unit | Breed | N  | Mean | SD  | Min  | Max  |
|-----------|------|-------|----|------|-----|------|------|
| DMI       | g/kg | Local | 88 | 81.7 | 20.0| 42.6 | 135  |
|           |      | Priangan | 33 | 79.9 | 19.5| 40.3 | 109  |
|           |      | Fat-tailed | 16 | 69.9 | 9.89| 59.6 | 93.8 |
| CPI       | g/kg | Local | 88 | 10.8 | 3.20| 4.65 | 21.1 |
|           |      | Priangan | 33 | 11.4 | 2.76| 5.90 | 17.5 |
|           |      | Fat-tailed | 16 | 9.76 | 1.71| 7.58 | 11.7 |
| EEI       | g/kg | Local | 46 | 4.63 | 2.92| 0.69 | 12.6 |
|           |      | Priangan | 30 | 3.54 | 2.36| 1.43 | 12.2 |
|           |      | Fat-tailed | 4  | 5.27 | 0.45 | 4.67 | 5.67 |
| CFI       | g/kg | Local | 46 | 18.2 | 7.59| 7.46 | 39.4 |
|           |      | Priangan | 30 | 14.0 | 7.41| 5.41 | 27.8 |
|           |      | Fat-tailed | 9  | 11.6 | 2.40| 8.46 | 14.5 |
| NDFI      | g/kg | Local | 34 | 40.6 | 7.84| 28.5 | 54.4 |
|           |      | Priangan | 5  | 43.7 | 3.32| 40.3 | 48.0 |
|           |      | Fat-tailed | na | na  | na  | na  | na  |
| ADFI      | g/kg | Local | 28 | 23.1 | 5.63| 14.3 | 31.7 |
|           |      | Priangan | 5  | 27.0 | 3.87| 22.6 | 32.0 |
|           |      | Fat-tailed | na | na  | na  | na  | na  |
| TDNI      | g/kg | Local | 46 | 53.3 | 17.9| 17.1 | 95.8 |
|           |      | Priangan | 26 | 49.7 | 12.5| 27.6 | 67.2 |
|           |      | Fat-tailed | 9  | 43.9 | 3.47| 39.6 | 49.1 |
| ADG       | g/kg | Local | 88 | 10.1 | 3.52| 2.26 | 21.1 |
|           |      | Priangan | 33 | 10.4 | 5.71| 1.90 | 26.9 |
|           |      | Fat-tailed | 16 | 10.0 | 5.09| 3.14 | 16.7 |
| G:F       | %    | Local | 88 | 13.0 | 5.64| 2.39 | 38.4 |
|           |      | Priangan | 33 | 12.4 | 4.52| 4.41 | 24.9 |
|           |      | Fat-tailed | 16 | 15.0 | 8.46| 4.61 | 24.4 |
| DMD       | %    | Local | 45 | 57.5 | 6.46| 49.0 | 73.6 |
|           |      | Priangan | 12 | 61.2 | 10.7| 43.8 | 76.0 |
|           |      | Fat-tailed | 16 | 74.1 | 5.52| 64.5 | 83.1 |
| NH<sub>3</sub> | mmol/L | Local | 6  | 9.06 | 1.57| 7.10 | 10.9 |
|           |      | Priangan | 12 | 6.55 | 2.70| 3.06 | 11.0 |
|           |      | Fat-tailed | 4  | 5.16 | 1.18| 3.70 | 6.35 |
| Total VFA | mmol/L | Local | 6  | 114  | 35.6| 73.5 | 150  |
|           |      | Priangan | 8  | 111  | 7.69| 95.0 | 118  |
|           |      | Fat-tailed | 4  | 175  | 15.3| 162  | 194  |

Note: N, number of data; SD, standard deviation; DMI, dry matter intake; CPI, crude protein intake; EEI, ether extract intake; CFI, crude fiber intake; NDFI, neutral detergent fiber intake; ADFI, acid detergent fiber intake; TDNI, total digestible nutrient intake; ADG, average daily gain; G:F, gain to feed; DMD, dry matter digestibility; NH<sub>3</sub>, ammonia; VFA, volatile fatty acid; MBW, metabolic body weight (BW<sup>0.75</sup>); na, data not available.
Weighting procedure was not applied in the present meta-analysis. An adjustment of dependent variable was performed to create a two-dimensional graphical presentation from multi-dimensional studies by adding the predicted dependent values with their corresponding residuals (St-Pierre, 2001). Maintenance and gain requirements for dry matter, energy and protein were determined by regressing ADG with DMI, TDNI and CPI, respectively. An intercept (where ADG=0 g/kg MBW/d) and a slope (required nutrient intake per unit ADG) indicated maintenance and gain requirements, respectively. The P-value and coefficient of determination ($R^2$) were employed to assess the goodness-of-fit of the statistical model. All statistical analyses were conducted by using SAS Software version 9.1.

RESULTS

There was a positive relationship between sheep BW$_0$ and DMI (Figure 1); higher BW$_0$ led to a higher DMI ($P<0.001$). Interactions between breed, sex and BW$_0$ on DMI were not significant. When DMI was presented as percentage to BW$_0$, the relationship became negative ($P<0.01$; Figure 2). A positive linear relationship between ADG and DMI was observed ($P<0.001$; Figure 3); such relationship was similar among different breeds and sex (no significant interaction). Crude protein intake (CPI) positively influenced ADG ($P<0.001$) and there was an interaction between CPI and breed on ADG ($P<0.05$; Table 2). No significant relationships were found between ether extract intake (EEI), crude fiber intake (CFI) and neutral detergent fiber intake (NDFI) on ADG. Similar to CPI, total digestible nutrient intake (TDNI) positively influenced ADG and it was specific for each breed ($P<0.001$). The CPI also positively influenced gain to feed ratio (G:F; $P<0.01$). Interactions between EEI and sex on G:F ($P<0.05$) and CPI and breed on G:F ($P<0.05$) were significant. Both NDFI and ADFI negatively influenced G:F ($P<0.05$) and the interaction between breed, sex and ADFI on G:F was significant ($P<0.01$). Intake of nutrients was hardly influenced DMD, rumen ammonia and total VFA concentrations.

All sheep breeds (local, Priangan and fat-tailed) had similar energy requirement for maintenance (TDN$_m$) as shown by the relatively similar intercept values among the breeds (Figure 4). Energy requirement for gain (TDN$_g$) of Priangan breed was lower than other breeds; the breed required 0.860 g TDN for 1 g ADG. Fat-tailed and local breeds required 1.22 and 2.75 g TDN for 1 g ADG, respectively. All breeds also revealed relatively similar protein requirement for maintenance (CP$_m$), i.e. 6.27-6.47 g/kg MBW/d (Figure 5). Priangan breed required less CP for 1 g ADG (CP$_g$), i.e. 0.295 g. Requirements of CP$_g$ for fat-tailed and local breeds were 0.336 and 0.497 g/g ADG, respectively. Based on the equations provided in Figure 4 and Figure 5, recommended dry matter, energy and crude protein intake for local, Priangan and fat-tailed sheep in Indonesia is presented in Table 3.

DISCUSSION

Dry Matter Intake of Sheep

Feed intake is considered as a primary factor determining performance of livestock. A positive relationship...
between sheep BW₀ and DMI was also observed in a meta-analysis study of Riaz et al. (2014). It was observed not only in sheep but also in other domestic ruminant species such as goat, cattle and buffalo. However, when DMI was presented proportionally to BW₀ then the relationship turned to be negative. It has been known that intake is directly related to maintenance requirement. With increasing body weight, maintenance requirement per unit of BW decrease and thus feed intake relative to BW decrease as well (Riaz et al., 2014). Using an equation presented in Figure 2, for instance, a sheep with 20 kg BW may require a DMI of 3.64% BW. The value is within the range of sheep DMI with similar BW, i.e. 2.86-3.91% BW as recommended by NRC (2007). Such NRC (2007) DMI recommendation range depends on ADG of sheep and energy concentration in the diet. The result was also in close agreement with Kearl (1982) who recommended that DMI of sheep (20 kg BW) ranged from 2.8%-3.6% BW.

Feed intake of ruminants is affected by a number of factors, i.e. dietary, animal and environmental factors (Nikkhah, 2014). Dietary factors affecting feed intake are comprised of feed physical and chemical properties, processing and fermentation rhythms. Animal factors affecting intake include parity, lactation stage (in the case of dairy animals), hormones, body fat stores and distribution, cellular hypoxia and energy flow, and production characteristics, whereas environmental

| Table 2. Significancy (P-value) of relationship between independent and dependent variables |
|---------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Dep    | Indep | Breed | Sex | B×S | Indep | B×I | S×I | B×S×I |
|--------|-------|-------|-----|-----|-------|-----|-----|-------|
| ADG    | DMI   | ns    | ns  | ns  | 0.005 | ns  | ns  | ns    |
| CPI    | ns    | ns    | ns  | 0.001 | 0.037 | ns  | ns  | ns    |
| EEI    | ns    | ns    | na  | ns  | ns    | ns  | ns  | na    |
| CFI    | ns    | ns    | na  | ns  | ns    | ns  | ns  | na    |
| NDFI   | ns    | ns    | ns  | ns  | ns    | ns  | ns  | ns    |
| ADFI   | ns    | ns    | ns  | 0.027 | ns    | ns  | ns  | ns    |
| TDNI   | ns    | na    | na  | <0.001 | <0.001 | na  | na  | na    |
| G:F    | DMI   | ns    | ns  | ns  | ns    | ns  | ns  | ns    |
| CPI    | ns    | ns    | ns  | 0.009 | ns    | ns  | ns  | ns    |
| EEI    | ns    | ns    | ns  | ns  | ns    | ns  | 0.044 | na    |
| CFI    | ns    | ns    | na  | ns  | 0.036 | ns  | na  | na    |
| NDFI   | ns    | ns    | ns  | ns  | ns    | ns  | ns  | ns    |
| ADFI   | ns    | ns    | na  | ns  | ns    | ns  | na  | na    |
| TDNI   | ns    | na    | na  | ns  | ns    | 0.023 | na  | na    |
| NH₃    | DMI   | ns    | na  | na  | ns    | ns  | na  | na    |
| CPI    | ns    | na    | na  | ns  | ns    | na  | na  | na    |
| EEI    | ns    | na    | na  | ns  | ns    | na  | na  | na    |
| CFI    | ns    | na    | na  | ns  | ns    | na  | na  | na    |
| NDFI   | ns    | na    | na  | ns  | ns    | ns  | na  | na    |
| ADFI   | na    | na    | na  | ns  | na    | na  | na  | na    |
| TDNI   | na    | na    | na  | ns  | na    | na  | na  | na    |
| Total  | DMI   | na    | na  | na  | ns    | ns  | na  | na    |
| VFA    | CPI   | ns    | na  | na  | ns    | ns  | na  | na    |
| EEI    | ns    | na    | na  | ns  | ns    | na  | na  | na    |
| CFI    | ns    | na    | na  | ns  | ns    | na  | na  | na    |
| NDFI   | ns    | na    | na  | ns  | ns    | ns  | na  | na    |
| ADFI   | na    | na    | na  | ns  | na    | na  | na  | na    |
| TDNI   | na    | na    | na  | ns  | na    | na  | na  | na    |

Note: Dep, dependent variable; Indep (I), independent variable; B, breed; S, sex. DMI, dry matter intake; CPI, crude protein intake; EEI, ether extract intake; CFI, crude fiber intake; NDFI, neutral detergent fiber intake; ADFI, acid detergent fiber intake; TDNI, total digestible nutrient intake; ADG, average daily gain; G:F, gain to feed; DMD, dry matter digestibility; NH₃, ammonia; VFA, volatile fatty acid; ns, not significant at P<0.05; na, data not available.
Table 3. Recommended dry matter, energy (total digestible nutrient, TDN) and crude protein (CP) intake for local, Priangan and fat-tailed sheep breeds in Indonesia

| BW (kg) | ADG (g/d) | Local (g/d) | Priangan (g/d) | Fat-tailed (g/d) |
|---------|-----------|-------------|----------------|-----------------|
|         | DM       | TDN         | CP             | DM              | TDN   | CP  |
| 10      | 0 324    | 152 35      | 324 159 36    | 324 155 36     |
|         | 50 434   | 289 60      | 434 202 51    | 434 216 52     |
|         | 100 544  | 427 85      | 544 245 66    | 544 277 69     |
|         | 150 654  | 564 110     | 654 288 81    | 654 338 86     |
| 15      | 0 439    | 206 48      | 439 215 49    | 439 210 48     |
|         | 50 549   | 343 73      | 549 258 64    | 549 271 65     |
|         | 100 659  | 481 97      | 659 301 79    | 659 332 82     |
|         | 150 769  | 618 122     | 769 344 94    | 769 393 99     |
| 20      | 0 545    | 255 59      | 545 267 61    | 545 260 60     |
|         | 50 655   | 393 84      | 655 310 76    | 655 321 77     |
|         | 100 765  | 530 109     | 765 353 91    | 765 382 93     |
|         | 150 875  | 668 134     | 875 396 105   | 875 443 110    |
| 25      | 0 644    | 302 70      | 644 315 72    | 644 307 71     |
|         | 50 754   | 439 95      | 754 358 87    | 754 368 88     |
|         | 100 864  | 577 120     | 864 401 102   | 864 429 104    |
|         | 150 974  | 714 145     | 974 444 117   | 974 490 121    |
| 30      | 0 738    | 346 80      | 738 361 83    | 738 353 81     |
|         | 50 848   | 484 105     | 848 404 98    | 848 414 98     |
|         | 100 958  | 621 130     | 958 447 112   | 958 475 115    |
|         | 150 1068 | 759 155     | 1068 490 127  | 1068 536 132   |

Note: BW, body weight; ADG, average daily gain.

Figure 4. Relationship between total digestible nutrient intake (TDNI, g/kg MBW/d) and average daily gain (ADG, g/kg MBW/d) of local (-○-), Priangan (-∆-) and fat-tailed (-□-) sheep breeds.

Local breed: TDNI (g/kg MBW/d) = 27.0 + 2.75 ADG (g/kg MBW/d) (N= 46; P<0.001; R²= 0.833)

Priangan breed: TDNI (g/kg MBW/d) = 28.2 + 0.860 ADG (g/kg MBW/d) (N= 26; P<0.001; R²= 0.829)

Fat-tailed breed: TDNI (g/kg MBW/d) = 27.5 + 1.22 ADG (g/kg MBW/d) (N= 9; P= 0.019; R²= 0.568)

Figure 5. Relationship between crude protein intake (CPI, g/kg MBW/d) and average daily gain (ADG, g/kg MBW/d) of local (-○-), Priangan (-∆-) and fat-tailed (-□-) sheep breeds.

Local breed: CPI (g/kg MBW/d) = 6.27 + 0.497 ADG (g/kg MBW/d) (N= 88; P<0.001; R²= 0.844)

Priangan breed: CPI (g/kg MBW/d) = 6.47 + 0.295 ADG (g/kg MBW/d) (N= 33; P<0.001; R²= 0.823)

Fat-tailed breed: CPI (g/kg MBW/d) = 6.33 + 0.336 ADG (g/kg MBW/d) (N= 16; P<0.001; R²= 0.851)

Numerous factors have been attempted to predict dry matter intake of ruminants, and body weight of the animals is considered as one of the most reliable factors for such prediction. Salah et al. (2014), for instance, estimated DMI from BW with a coefficient determination...
of 0.91. The NRC (2007) also used BW in the terms of standard reference weight and relative size to estimate intake of sheep with a number of correction factors such as sheep physiological state and diet quality (legume content and quality of the legume).

**Energy Requirement of Sheep**

Expression of energy intake found in feeding experiments using sheep in Indonesia was generally in the form of TDN. This energy system is actually not ideal and therefore, current system has to be moved towards metabolizable energy (ME) or even net energy (NE) system (NRC, 2007; Van Duinkerken et al., 2011; Van Amburgh et al., 2015). Further, TDN data from various diets were obtained by estimations from their chemical composition and seldomly derived experimentally; such predictions may not be accurate since no study so far, to our knowledge, has validated the relationship between estimated TDN and measured TDN in the country. It is apparent that in the future we should update our energy system. Measurement of gross energy (GE) is presently available in many laboratories related to animal nutrition in Indonesia. Derivation of digestible energy (DE) value is relatively simple by combining GE intake and digestibility coefficient of the diet. Determination of ME requires a certain equipment to measure loss of energy as methane. In the case of unavailable or insufficient data of methane emissions across various dietary regimes, a number of equations to estimate methane emissions from sheep are available (Sejian et al., 2011; Vetharaniam et al., 2015) and may be used to derive ME from DE data.

Requirement of TDN obtained in the present study is apparently higher in comparison to the recommendation of NRC (2007). For instance, a growing lamb with BW of 20 kg and ADG 100 g/d requires 300 g TDN/d (NRC, 2007). At similar BW and ADG, local sheep, Priangan and fat-tailed breeds require 530, 353 and 382 g TDN/d, respectively. Nevertheless, Kearl (1982) suggested that sheep with such BW and ADG required 470 g TDN/d which is in accordance with our present result. Salah et al. (2014) reported that, by using a meta-analysis study, ME\_\text{requirement}\_\text{of\_tropical}\_\text{and}\_\text{temperate\_sheep}\_\text{are}\_423.7\_\text{and}\_361.2\_\text{kj/g\_MBW,\_respectively.}\_\text{These\_value\_are\_equal\_to}\_28.1\_\text{and}\_23.9\_\text{g\_TDN/kg\_MBW/d,\_respectively,\_taking\_into\_consideration\_that}\_1\_\text{kg\_TDN=\_4.4\_Mcal\_DE\_and\_ME=\_DE\_\times\_0.82\_(NRC,\_2007).}\_Our\_TDN\_values\_ranged\_from\_27.0\_\text{to}\_28.2\_\text{g/kg\_MBW/d\_which\_were\_quite\_comparable\_to\_the\_value\_of\_ME\_of\_tropical\_sheep\_(Salah\_et\_al.,\_2014).\_Further,\_ME\_of\_tropical\_and\_temperate\_sheep\_are\_17.6\_\text{and}\_16.4\_\text{kJ/g\_ADG,\_respectively\_(Salah\_et\_al.,\_2014),\_which\_are\_equal\_to\_1.166\_\text{and}\_1.086\_\text{g\_TDN/g\_ADG.}\_In\_comparison\_to\_such\_recommendation,\_our\_TDN\_value\_was\_lower\_for\_Priangan\_breed\_but\_higher\_for\_local\_and\_fat-tailed\_breeds.\_Our\_results\_suggested\_a\_higher\_TDN\_requirement\_in\_comparison\_to\_NRC\_(2007)\_standard.\_To\_make\_the\_recommendation,\_NRC\_(2007)\_employed\_a\_database\_from\_31\_references\_with\_156\_observations\_from\_1,875\_sheep\_in\_which\_the\_sheep\_genotype\_presented\_was\_of\_temperate\_origin\_such\_as\_Dorset,\_Rambouillet,\_St.\_Croix,\_Hampshire,\_Suffolk\_and\_many\_others.\_On\_the\_contrary,\_our\_database\_was\_developed\_by\_using\_sheep\_genotype\_of\_tropical\_origin\_and\_thus\_apparently\_more\_appropriate\_with\_the\_recommendation\_of\_Kearl\_(1982).\_Tropical\_genotypes\_generally\_are\_not\_selected\_for\_muscle\_deposition\_and,\_hence,\_tend\_to\_be\_fatter\_as\_compared\_to\_those\_of\_temperate\_genotypes\_(Chay-Canul\_et\_al.,\_2011).\_In\_consequence,\_tropical\_genotypes\_require\_more\_energy\_for\_ADG\_than\_the\_temperate\_genotypes.\_Further,\_under\_high\_temperature\_conditions\_prevailing\_in\_the\_tropics,\_sheep\_require\_more\_energy\_to\_dissipate\_body\_heat\_and\_therefore\_increase\_the\_energy\_requirement\_of\_the\_animal\_(CSIRO,\_2007).\_Another\_factor\_that\_may\_explain\_such\_higher\_energy\_requirement\_of\_sheep\_obtained\_in\_this\_study\_is\_the\_diet.\_Tropical\_sheep\_are\_generally\_fed\_with\_agricultural\_by-products\_that\_rich\_in\_fiber\_contents\_(Zain,\_2009;\_Ginting\_et\_al.,\_2013;\_Ndaru\_et\_al.,\_2014).\_Such\_fibrous\_feeds\_may\_increase\_heat\_production,\_visceral\_energy\_consumption,\_energy\_needed\_for\_intake\_and\_chewing,\_energy\_expenditure,\_and\_finally\_total\_energy\_requirement\_of\_ruminants\_(Salah\_et\_al.,\_2014).\_Comparing\_among\_different\_sheep\_breeds\_evaluated\_in\_the\_present\_meta-analysis\_study,\_it\_was\_clear\_that\_the\_order\_of\_TDN\_requirement\_was\_as\_follow:\_Priangan<fat-tailed<local.\_This\_indicates\_that\_Priangan\_sheep\_is\_more\_efficient\_in\_converting\_energy\_intake\_into\_body\_mass\_as\_compared\_to\_the\_other\_two\_breeds,\_and\_local\_breed\_is\_the\_least\_efficient.\_This\_result\_is\_in\_agreement\_with\_Sumantri\_et\_al.\_(2007)\_who\_observed\_that\_body\_weight\_and\_body\_size\_of\_Priangan\_(Garut)\_sheep\_were\_higher\_as\_compared\_to\_other\_breeds,\_including\_local\_sheep\_from\_Jonggol\_and\_fat-tailed\_sheep\_from\_various\_locations\_(Madura,\_Donggala,\_Kisar,\_Rote,\_and\_Sumbawa).\_It\_seems\_that\_genetic\_potential\_of\_Priangan\_sheep\_is\_better\_since\_the\_breed\_was\_a\_cross\_between\_local,\_Merino\_and\_fat-tailed\_sheep\_(Inouu,\_2011),\_thus\_inherited\_all\_the\_excellent\_characteristics\_from\_the\_three\_breeds.\_Additionally,\_Priangan\_sheep\_have\_been\_genetically\_selected\_for\_superior\_agility\_and\_accompanied\_with\_good\_feeding\_and\_raising\_practices\_particularly\_in\_Garut\_region\_(Inouu,\_2011).\_On\_the\_contrary,\_local\_sheep\_receive\_much\_less\_attention\_with\_regard\_to\_genetic\_selection,\_breeding,\_feeding\_and\_management\_practices\_thus\_contributing\_to\_their\_low\_production\_merit.\_Body\_compositions\_of\_different\_sheep\_breeds\_apparently\_also\_influence\_their\_TDN\_requirements.\_Baihaqi\_\&\_Herman\_(2012)\_reported\_that\_carcass\_of\_Priangan\_breed\_had\_more\_muscle\_and\_less\_fat\_at\_mature\_live\_weight\_than\_that\_of\_fat-tailed\_breed.\_At\_a\_slaughter\_weight\_of\_32.5\_kg,\_Priangan\_breed\_contained\_4.85\_kg\_muscle\_and\_2.28\_kg\_fat,\_whereas\_fat-tailed\_breed\_contained\_4.49\_kg\_muscle\_and\_2.73\_kg\_fat.\_Similarly,\_at\_a\_slaughter\_weight\_of\_40\_kg,\_muscle\_contents\_in\_Priangan\_and\_fat-tailed\_breeds\_were\_5.70\_and\_5.03\_kg,\_respectively,\_while\_their\_fat\_contents\_were\_2.66\_and\_3.70\_kg,\_respectively\_(Baihaqi\_\&\_Herman,\_2012).\_Since\_fat\_synthesis\_requires\_more\_energy,\_it\_is\_therefore\_obvious\_that\_fat-tailed\_sheep\_require\_more\_TDN\_than\_that\_of\_Priangan.\_\_
Protein Requirement of Sheep

Expression of protein intake found in feeding experiments using sheep in Indonesia was in the form of crude protein (CP). This system is less accurate and current system has to be shifted to metabolizable protein (MP) system or its equivalent (NRC, 2007; Van Duinkerken et al., 2011; Das et al., 2014; Owens et al., 2014; Van Amburgh et al., 2015). The old CP system has a main disadvantage, i.e. it does not differentiate between protein requirement of rumen microbes and protein requirement of the host animal (Das et al., 2014). The MP system, conversely, addresses both the need of N for rumen microbes and postruminal need of amino acids for maintenance and growth of the host ruminant (Owens et al., 2014). By employing the MP system, basic goals in protein nutrition of ruminants can be achieved, i.e. (1) to meet rumen degradable protein (RDP) requirement of rumen microbes for maximum carbohydrate digestion and microbial protein synthesis, (2) to meet MP requirement of host animal for maintenance, growth, optimum health, and reproduction with minimum intake of rumen undegradable protein (RUP), and (3) to meet MP and amino acids requirements of the host animal for a desired production level with minimum dietary CP (Das et al., 2014). Even though MP system is preferable as compared to CP system, such application may be difficult due to limited data available like the case in Indonesia. An alternative solution is to predict MP from CP; dietary MP concentration ranges from 64 to 80% of CP with diets of 0 to 100% of RUP, respectively (NRC, 2007). So if the proportion of RUP is known then MP can be estimated. But if RUP is unknown then using CP system is still acceptable (Owens et al., 2014).

As of TDN, CP requirement of Indonesian sheep obtained by using meta-analysis approach is higher than the NRC (2007) recommendation. Local, Priangan and fat-tailed sheep with BW 20 kg and ADG 100 g/d would require 109, 91 and 93 g CP/d, respectively, whereas NRC (2007) recommends 69-76 g CP/d that depends on RUP proportion in the diet; higher RUP proportion leads to lower CP requirement. Accordingly, Kearl (1982) recommended 72 g CP/d for sheep with similar BW and ADG. Salah et al. (2014) reported that digestible CP (DCP) requirements of tropical and temperate sheep genotypes were similar; DCP requirement for maintenance (DCP_m) and gain (DCP_g) was 2.8 g/kg MBW and 0.2 g/g ADG, respectively. Assuming a CP digestibility of 70% in mixed diets consumed by sheep (Zagorakis et al., 2015; Aemiro et al., 2017), the CP_m and CP_g requirements become 4.0 g/kg MBW and 0.286 g/g ADG, respectively. Our CP_m and CP_g values for all sheep breeds evaluated were higher in comparison to those of Salah et al. (2014). It has to be noted that such CP requirements may have to be adjusted according to variation in dietary CP digestibility; among the factors that influence the digestibility or nitrogen retention are nitrogen intake, faecal nitrogen excretion and urinary nitrogen excretion (Schuba et al., 2017). Further, presence of dietary factors that influence the proportion between RDP to RUP may also change CP requirement. Among them are polyphenols or tannins that shift towards more RUP proportion since the compounds are able to form complexes with dietary protein and protect the nutrient from microbial degradation in the rumen (Jayanegara et al., 2013; 2015).

Higher CP requirement obtained in this study probably is a reflection of the difference between tropical and temperate sheep breeds in which the tropical breed has generally lower growth potential (Chay-Canul et al., 2011) as previously described. High environmental temperature in the tropics may also explain such high CP_m and CP_g requirements obtained in the current study. It has been described that high temperature is associated with an increase of absorbed amino acid requirement for growth in ruminants (Salah et al., 2014). Lower CP_m requirement of Priangan breed confirms superiority of the breed as compared to fat-tailed and local breeds (Sumatri et al., 2007; Inouui, 2011).

CONCLUSION

Each sheep breed in Indonesia has specific TDN and CP requirements. Although energy and protein requirements for maintenance (TDN_m and CP_m) are similar across sheep breeds, different sheep breeds have significantly different energy and protein requirements for gain (TDN_g and CP_g). Priangan sheep requires less TDN_g and CP_g in comparison to fat-tailed and local breeds, and local breed possesses higher TDN_m and CP_m requirements than those of the fat-tailed. Further studies are required to validate the current results of energy and protein requirements for Indonesian sheep.

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