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REGULAR ARTICLES

Nutrient intake, growth performance and nutrient digestibility of pre- and post-weaning Dorper lambs fed varying crude protein level

Mira Panadi[1,2] · **Khairiyah Mat**[3,4] · **Mohammad Mijanur Rahman**[3,4] · **Mohd Azam Khan Goriman Khan**[2] · **Malarvili Balakrishnan**[1] · **Nor Dini Rusli**[3,4]

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Abstract

The objective of the present study was to investigate the effect of varying crude protein (CP) levels on intake, growth performances and nutrient digestibility of Dorper lambs at pre- and post-weaning period. Twenty lambs at 7 days old with an initial body weight of 2.91 kg were individually penned and randomly assigned into four (4) dietary groups using a randomised complete block design. In Trial I, pre-weaning lambs were fed with creep feeding (CF) diet containing 14% crude protein (CP) as a control diet (CON14), 16% (CF16), 18% (CF18) and 20% (CF20) of CP for 84 days. Following Trial 1, the animals were fed with a growing ration (GR) diet for 96-day feeding trial. The diets consisted of 11% CP as a control diet (CON11), 14% (GR14), 16% (GR16) and 18% (GR18) of CP. The water was available ad libitum and the feed intake was measured daily by the difference of feed offered and refused. The increase of CP level resulted in a linear increase of dry matter intake (DMI), nutrient intake and average daily gain (ADG) in pre- and post-weaning lambs. The DMI (g/day) of lambs fed with CF20 (1059.92) was significantly higher ($p < 0.05$) than CON14 (605.30), but it did not differ significantly with CF16 (866.80) and CF18 (680.40). Besides, the DMI (g/day) of lambs fed GR18 was found significantly higher than CON11 and GR16. In pre- and post-weaning lambs, there was a quadratic effect of increased CP level on the ADG. The ADG (g/day) of pre-weaning lambs fed with CF18 (247.86) and CF20 (251.28) were not significantly different ($p > 0.05$) compared to those fed with CF16 (217.95). For post-weaning lambs, GR16 had significantly higher ADG than CON11 (43.14), but it was no difference with GR14 (72.94) and GR18 (69.41). However, increased CP level resulted in linear increase of DM, ash, organic matter (OM) and CP digestibility. The present finding suggested that the optimum CP level for pre- and post-weaning Dorper lambs in Malaysia was 16% and 14%, respectively.

Keywords Creep feed · Growing ration · Sheep

Introduction

An adequate level of protein in livestock feed is essential for optimal microbial growth and protein synthesis. Excessive protein intake could lead to large waste production, particularly nitrogen (N), leading to environmental pollution (Chandrasekharaiah et al. 2011). Besides, sufficient protein is required for growth and development. Feeding animals according to their crude protein (CP) requirements is important to reduce risk associated with excess and deficiency of CP (Abbasi et al. 2014). Nutritional deficiency is the main factor that limits animal performance (Mira et al. 2019). A previous study on thin-tailed lambs fed with varying levels of protein in the diet showed that increasing crude protein (CP) higher than 18% did not increase the average daily gain (ADG) (Ebrahimi et al. 2007). At this

✉ Nor Dini Rusli
nordini@umk.edu.my

1 Department of Clinical Sciences and Sport Technology, School of Biomedical Engineering and Health Sciences, Universiti Teknologi Malaysia, Jalan Pontian Lama, Skudai, 81300 Johor Bahru, Johor, Malaysia

2 Department of Pre-Clinical Studies, Faculty of Veterinary Medicine, Universiti Malaysia Kelantan, Locked Bag 36, 16100 Pengkalan Chepa, Kota Bharu, Kelantan, Malaysia

3 Department of Agriculture Science, Faculty of Agro-Based Industry, Universiti Malaysia Kelantan, 17600 Jeli, Kelantan, Malaysia

4 Institute of Food Security and Sustainable Agriculture, Universiti Malaysia Kelantan Jeli Campus, 17600 Jeli, Kelantan, Malaysia

level, the increase of CP level was not balanced by energy content in the feed (Prima et al. 2019). Several studies reported that enhancing dietary protein levels in lambs could improve dry matter intake (DMI), growth rate, wool growth and feed conversion ratio (FCR) (Milis et al. 2005; Thomas et al. 2007; Chandrasekharaiah et al. 2011).

The CP is an important nutrient for growing sheep, and ingredients with a high CP content are often expensive. There are various protein requirement recommendations for lambs, suggesting that more research is needed to determine the protein requirements of lambs, especially at growing stages. Various studies on the CP requirements of lambs have yielded a variety of results. According to a report, Santa Ines, Suffolk and Merino lambs require 20%, 17.5% and 23.7% of CP, respectively (Rocha et al. 2004).

Creep feeding is the method of providing an opportunity for nursing lambs to eat high-quality feed other than milk from dams and forage (Brand and Brundyn 2015). It is often formulated using common ingredients that are costly (Venkateswarlu et al. 2012). A critical stage in the weight gain of lambs is the transition from monogastric (pre-ruminant) to ruminant. Early life supplementation will improve this process and future performance and familiarise the animal with concentrate consumption (Martinez et al. 2015). Nevertheless, as reviewed by Browning et al. (2011), other factors such as breed, litter size and sex have consistently affected pre-weaning performance.

The appropriate CP level for pre-weaning Dorper lambs fed on creep feed is uncertain due to a minimal number of studies, especially in Malaysia (Norhayati et al. 2018). Besides, post-weaning performance is significantly influenced by pre-weaning performance (Bhatt et al. 2009). The low fibre diet with high starch content is commonly fed in growing ration to increase energy intake, resulting to metabolic disorders such as acidosis and displaced abomasum (Yansari and Promohammadi 2009).

Dorper sheep had been introduced to Malaysia to enhance local meat production (Norhayati et al. 2018). This breed is highly adaptable to adverse temperature with outstanding carcass composition (Cruz et al. 2017). However, the growth of this breed is still low as most farmers were not aware of creep feeding practice at an early age of lamb. In a commercial farm, creep feeding practices only using commercial creep pellet that often causes a digestive problem due to overconsumption of concentrate feed. Besides, poor performance during pre-weaning stages had negatively influenced post-weaning performance. The feeding of creep and grower ration in total mixed ration (TMR) involves the combination of forage, grains, vitamin and mineral supplements that are nutritionally balanced, and adequate nutrients for optimum animal performance (Cooke et al. 2004).

However, little is known about the CP requirement for Dorper lambs raised in Malaysia. The current recommended level of CP requirements for pre- and post-weaning lambs was based on a recommendation for small ruminants established by NRC (2007). Hence, it was hypothesised that CP requirements for pre- and post-weaning lambs were 18% and 16% respectively. Therefore, this study was conducted to determine the CP requirement of Dorper lambs at pre- and post-weaning stages and evaluate the effect of feeding varying CP levels on DMI, nutrient intake, growth performance and nutrient digestibility of pre- and post-weaning Dorper lambs.

Materials and methods

Study area

This study was conducted at Agropolitan Besut Setiu Farm, Terengganu, Malaysia (latitude 5° 27′ N and longitude of 102° 53′ E) from March 2019 to September 2019.

Animals and experimental design

Twenty (20) Dorper lambs with a mean initial body weight of 2.91 ± 0.07 kg at seven (7) days old were randomly assigned into four (4) dietary treatment groups with five (5) lambs in each treatment group using randomised complete block design for 84 day-feeding trial at pre-weaning stage. Four (4) dietary treatments included a control group which consisted of basal diet and creep feed at different CP levels which were 14% (CON14); 16% (CF16); 18% (CF18) and 20% (CF20) of CP. The lambs were separated in individual pen measuring 1.5 m × 1.2 m in an animal shed at 2 m above the ground. The lambs were allowed to suckle at all times until day 84 of pre-weaning period except during feeding their mother to prevent the lambs from consuming the mother's feed.

At the end of the pre-weaning stage, all lambs from creep feed groups were then fed with grower rations (GR) containing 11% CP (CON11), 14% CP (GR14), 16% CP (GR16) and 18% CP (GR18), respectively, for another 96 days. The formulation of control diet consisted of Napier grass and commercial creep and grower pellet for pre- and post-weaning lambs, respectively, whereas treatment rations consisted of Napier grass, copra cake, palm kernel cake, soybean meal, soy hull, rice bran, molasses, mineral premix and salt. The formulated feed was prepared on a daily basis. The Napier grass at 40 days of plant maturity was harvested daily and chopped at about 2 cm length before fed to the lambs. The forage to concentrate ratio for during pre- and post-weaning stages was maintained at 40:60 and 60:40 respectively (Urbano et al., 2017).

The control and treatment rations were formulated by varying the CP levels, while metabolizable energy (ME) was maintained at the recommended level of 11 MJ/kg DM ME (NRC, 2007). The feed intake of lambs was based on 3.5% of body weight. The diets were offered equally in a separate meal in the morning (9:00 a.m.) and evening (3:00 p.m.) with free access of clean drinking water. The feed was adjusted by two (2) weeks interval based on body weight changes. Table 1 shows the composition of control and treatment rations in different formulation.

Digestibility trial

At the end of 180 days feeding trial, all post-weaning lambs were assigned in individual digestibility cages. A digestion trial was conducted for seven (7) days of faecal collection period. The daily faecal excreted for individual lambs were recorded and 10% of the faecal was subsampled. The subsample of individual lambs was pooled and frozen at – 5 °C. After the digestibility trial, the samples were dried at 60 °C for 48 h and ground for further chemical analysis. The total urine output was also collected and measured daily. The urine samples were collected in a container containing 0.036 N sulphuric acid at a ratio of 1:4 of urine to acid to prevent urinary ammonia loss and microbial contamination. The mixture was frozen for further analysis to determine the N content by the Kjeldahl method (AOAC, 1997).

Chemical analysis

Samples were analysed for dry matter (DM), ash and crude protein (CP) following the method of AOAC (1997). The ether extract (EE) was determined by Foss Extraction system (Foss, Gerhardt, Germany) by extraction with petroleum ether. The crude fibre (CF), acid detergent fibre (ADF) and neutral detergent fibre (NDF) were determined as described by Van Soest et al. (1991). The sodium (Na), magnesium (Mg), potassium (K), calcium (Ca), manganese (Mn), iron (Fe), cobalt (Co), copper (Cu) and selenium (Se) were measured based on standard analytical method using Atomic Absorption Spectrometry (AAS) (Perkin Elmer 1996), whereas the phosphorus (P) was determined by spectrophotometric-colorimetric method (AOAC, 1995).

The organic matter (OM), nitrogen free extract (NFE), total digestible nutrient (TDN) and ME were calculated based on the following equations:

$$\text{OM (\%)} = 100 - \text{\% Ash}$$

$$\text{NFE (\%)} = 100 - (\text{\% CP} + \text{\% CF} + \text{\% EE} + \text{\% Ash})$$

$$\text{TDN} = 5.31 + 0.412\ \text{CP\%} + 0.249\ \text{CF\%} + 1.444\ \text{EE\%} + 0.937\ \text{NFE\%}$$

$$\text{ME} = 0.185\ \text{TDN} - 1.89$$

Data collection

The daily feed intake was measured as the difference in the amount of feed offered and feed refused. The sample of feed offered and refused was collected for DM analysis to determine daily DMI. Based on the data of DMI and chemical composition of feed, nutrient intakes were calculated based on the following equation:

$$\text{Nutrient intake (g/day)} = \text{daily DMI (g)} \times \text{nutrient content in feed (\%)}$$

Table 1 Composition (%) of creep feed and grower ration in different formulation

Ingredients (%)	Trial I			Trial II		
	CF16	CF18	CF20	GR14	GR16	GR18
Napier grass	40	40	40	60	60	60
Palm kernel cake	-	-	-	3.7	3.7	0
Copra cake	20.5	18.4	18.4	13.7	6.8	10.5
Soybean meal	10.5	16.9	23.5	9.9	16.8	23.3
Corn meal	-	-	-	5.5	5.5	4
Soy hull	17.8	16.8	12.9	5	5	0
Rice bran	9	5.6	2	-	-	-
Molasses	2	2.1	3	2	2	2
Mineral premix	0.1	0.1	0.1	0.1	0.1	0.1
Salt	0.1	0.1	0.1	0.1	0.1	0.1

Ingredients in mineral premix (per 50 g) (Glovet Premix Plus, Global Veterinary) consisted of 320 mg Mn, 200 mg Zn, 1500 mg Mg, 500 mg Fe, 50 mg Cu, 15 mg Co, 20 mg iodate, 10 g P, 5500 mg salt, 1300 mg Ca, 50 000 i.u Vitamin A, 8000 i.u Vitamin D3, 10 mg Vitamin E

Mineral premix also contains formic acid, citric acid, malic acid, tartaric acid, lactic acid and orthophosphoric acid

CF16 creep feed at 16% of CP, *CF18* creep feed at 18% of CP, *CF20* creep feed at 20% of CP, *GR14* grower ration at 14% of CP, *GR16* grower ration at 16% of CP, *GR18* grower ration at 18% of CP

The lambs were weighed at 2 weeks interval in the morning before the feeding to evaluate the growth performance. Average daily gain (ADG) was calculated as the difference of initial and final weight over the experimental period.

Expected DMI and ADG were modelled (Generalised Linear Model of SPSS) as described by Lima et al. (2017). The residual feed intake (RFI) was determined by linear regression of DMI against metabolic body weight and ADG during the trial. The RFI was determined by subtraction of expected feed intake minus actual feed intake. The residual body weight gain (RWG) was modelled by a linear regression model of ADG based on DMI and metabolic body weight while the residual intake gain (RIG) is a linear function of both RFI and RWG. It was calculated as the sum of $-1 \times$ RFI and RWG, both standardised to a variance of 1.

Data analysis

The data of DMI, nutrient intake, ADG, body weight changes, nutrient digestibility and RWG were analysed statistically by one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS Inc., Chicago, USA). If there were a significant difference between treatments ($P < 0.05$), the data were tested by Duncan multiple range test. Linear and quadratic effects of different CP level were also tested.

Results

The chemical composition of treatment rations for creep feed and grower ratio at different CP levels fed to the lambs in two different feeding trial is shown in Table 2. The CP (%) of CF16, CF18 and CF20 was 16.17, 18.17 and 20.12, respectively, while GR14, GR16 and GR18 were 13.53, 15.51 and 17.62%, respectively.

Table 3 shows the chemical composition of basal diet for pre- and post-weaning lambs. The CP % of commercial grower and breeder pellets was 18.26% and 15.78% respectively, whereas the ME content was similar at 11 MJ/kg DM ME. The CP and ME contents of Napier grass were found low at 8.06% and 9.93 MJ/kg DM, respectively.

Table 2 Chemical composition (mean ± standard error) of formulated creep feeds and grower rations

Parameters	Trial I			Trial II		
	CF16	CF18	CF20	GR14	GR16	GR18
DM (%)	61.63 ± 0.55	61.53 ± 0.87	61.32 ± 0.36	47.08 ± 0.40	46.88 ± 0.56	46.95 ± 0.20
Ash (%)	7.81 ± 0.15	7.43 ± 0.19	6.39 ± 0.37	5.12 ± 0.01	4.65 ± 0.02	4.25 ± 0.01
OM (%)	92.19 ± 0.15	92.57 ± 0.19	93.61 ± 0.37	94.88 ± 0.01	95.35 ± 0.02	95.75 ± 0.01
CP (%)	16.17 ± 0.51	18.17 ± 0.15	20.12 ± 0.62	13.53 ± 0.38	15.51 ± 0.20	17.62 ± 0.08
EE (%)	6.76 ± 2.24	4.87 ± 0.12	3.94 ± 0.26	3.04 ± 0.05	2.40 ± 0.13	2.32 ± 0.10
CF (%)	24.54 ± 0.15	20.63 ± 0.45	21.05 ± 1.05	30.44 ± 0.14	28.95 ± 0.20	27.41 ± 0.21
ADF (%)	49.99 ± 0.50	29.70 ± 1.20	27.98 ± 1.30	33.92 ± 0.55	31.31 ± 1.00	29.26 ± 0.56
NDF (%)	43.85 ± 0.57	47.25 ± 1.35	44.50 ± 1.15	58.18 ± 1.00	54.17 ± 1.20	50.68 ± 0.09
NFE (MJ/kg DM ME)	43.85 ± 0.57	48.90 ± 0.61	46.17 ± 0.90	42.95 ± 0.81	40.15 ± 1.15	36.84 ± 0.90
TDN (%)	68.39 ± 1.68	70.78 ± 0.85	66.49 ± 1.10	59.74 ± 0.87	54.89 ± 0.95	50.52 ± 0.75
ME (MJ/kg DM)	11.00 ± 0.07	11.20 ± 0.16	11.02 ± 0.20	10.56 ± 0.13	10.53 ± 0.16	10.54 ± 0.34
Na (mg)	0.49 ± 0.28	Saturated	5.23 ± 0.30	6.65 ± 0.23	7.20 ± 1.34	3.50 ± 1.78
Mg (mg)	0.13 ± 0.08	0.54 ± 0.31	0.15 ± 0.09	4.47 ± 0.13	5.68 ± 1.88	5.44 ± 1.43
P (mg)	0.26 ± 0.15	0.59 ± 0.34	0.17 ± 0.10	7.45 ± 0.57	9.35 ± 0.89	7.20 ± 1.00
K (mg)	Saturated	Saturated	Saturated	Saturated	Saturated	Saturated
Ca (mg)	0.04 ± 0.02	1.41 ± 0.82	0.02 ± 0.01	9.17 ± 0.89	8.83 ± 1.13	7.93 ± 1.12
Mn (mg)	0.001 ± 0.0006	0.01 ± 0.006	0.006 ± 0.003	0.20 ± 0.09	0.16 ± 0.09	0.17 ± 0.05
Fe (mg)	0.04 ± 0.02	0.05 ± 0.03	0.003 ± 0.001	0.47 ± 0.09	0.80 ± 0.02	0.59 ± 0.09
Co (mg)	0.01 ± 0.001	0.13 ± 0.001	0.03 ± 0.001	2.15 ± 0.23	0.25 ± 0.12	1.1 ± 0.57
Cu (mg)	ND	ND	ND	0.02 ± 0.002	ND	0.0004 ± 0.00001
Se (mg)	ND	ND	ND	ND	ND	ND

CF16 creep feed at 16% of CP, *CF18* creep feed at 18% of CP, *CF20* creep feed at 20% of CP, *GR14* grower ration at 14% of CP, *GR16* grower ration at 16% of CP, *GR18* grower ration at 18% of CP

ND not determined, *DM* dry matter, *OM* organic matter, *CP* crude protein, *EE* ether extract, *CF* crude fibre, *ADF* acid detergent fibre, *NDF* neutral detergent fibre, *NFE* nitrogen free extract, *TDN* total digestible nutrient, *ME* metabolise energy, *Na* sodium, *Mg* magnesium, *P* phosphorus, *K* potassium, *Ca* calcium, *Mn* manganese, *Fe* ferum, *Co* cobalt, *Cu* copper, *Se* selenium

Table 3 Chemical composition (mean ± standard error) of basal diet (control)

Parameters	Napier grass	Commercial creep pellet	Commercial grower pellet
DM (%)	18.80 ± 0.15	87.68 ± 0.03	90.65 ± 0.04
Ash (%)	5.38 ± 0.09	4.54 ± 0.01	4.74 ± 0.07
OM (%)	94.62 ± 0.09	95.46 ± 0.01	95.26 ± 0.07
CP (%)	8.06 ± 0.11	18.26 ± 0.27	15.78 ± 0.08
EE (%)	1.95 ± 0.02	2.84 ± 0.09	5.67 ± 0.11
CF (%)	39.01 ± 1.02	21.88 ± 0.51	20.99 ± 1.13
ADF (%)	41.81 ± 1.45	31.07 ± 0.21	29.21 ± 0.75
NDF (%)	70.04 ± 1.03	50.00 ± 0.55	48.43 ± 0.09
NFE (%)	45.60 ± 1.19	52.49 ± 0.84	52.82 ± 1.16
TDN (%)	63.89 ± 0.85	71.56 ± 0.43	74.72 ± 0.87
ME (MJ/kg DM)	9.93 ± 0.16	11.35 ± 0.08	11.93 ± 0.16

DM dry matter, *OM* organic matter, *CP* crude protein, *EE* ether extract, *CF* crude fibre, *ADF* acid detergent fibre, *NDF* neutral detergent fibre, *NFE* nitrogen free extract, *TDN* total digestible nutrient, *ME* metabolise energy

The DMI (g/day) of pre-weaning lambs fed CF20 (1059.92) was significantly ($P < 0.05$) higher than the CON14 (605.30) (Table 4). On the contrary, no significant ($P > 0.05$) differences of DMI were observed between CF20 (1059.92), CF16 (866.80) and CF18 (680.40). There was also a significant ($P < 0.05$) effect of different levels of CP on ash, OM, CP and EE intakes, except for CF intake. The ash, CP and EE intakes were also increased linearly ($P < 0.05$) with increasing levels of CP. On the other hand, only EE intake was quadratically increased ($P < 0.05$) with increasing levels of CP. Table 4 also shows the increase of CP level in post-weaning diet has resulted in a linear increase of total DMI and nutrient intake. The DMI (g/day) of lambs fed on GR18 (1685.85) was significantly ($P < 0.05$) higher than those fed on GR16 (1252.15) and the CON11 (1194.92). Besides, the OM, CP and EE intakes in GR14 and GR18 were also significantly ($P < 0.05$) higher than CON11 and GR16.

Table 5 shows the growth performance of pre- and post-weaning lambs. The final weight (kg) of pre-weaning lambs in CF20 (25.90) was significantly ($P < 0.05$) higher than those in control (20.67) and CF16 (22.60). Moreover, results showed that the final weight was increased linearly ($P < 0.05$) with an increasing level of CP. Besides, the ADG (g/day) of pre-weaning lambs in CF18 (247.86) and CF20 (251.28) was significantly ($P < 0.05$) higher than CON14 (196.58). Total ADG was in the following order: CF20 (251.28) > CF18 (247.8 6) > CF16 (217.95) > CON14 (196.58). Additionally, ADG and body weight were increased linearly ($P < 0.05$) with increasing levels of CP. However, the ADG between pre-weaning

Table 4 Dry matter (g/day) and nutrient intakes (g/day) of pre- and post-weaning Dorper lambs

Parameters	Treatments group (mean ± standard error)				*P* value	
Trial I (pre-weaning)	CON14	CF16	CF18	CF20	Linear	Quadratic
DMI of Napier grass	326.57 ± 58.79	-	-	-	-	-
DMI of commercial creep pellet	278.72 ± 20.58	-	-	-	-	-
Total DMI	605.30 ± 70.96[a]	866.80 ± 59.68[ab]	680.40 ± 65.64[ab]	1059.92 ± 72.31[b]	0.040	0.639
Total ash intake	30.22 ± 5.65[a]	67.70 ± 4.66[b]	50.55 ± 19.74[ab]	67.73 ± 4.62[b]	0.030	0.265
Total OM intake	575.07 ± 10.31[a]	799.10 ± 55.02[ab]	629.84 ± 21.22[ab]	992.19 ± 67.69[b]	0.054	0.553
Total CP intake	77.22 ± 10.71[a]	140.16 ± 9.65[b]	123.63 ± 48.27[b]	213.26 ± 14.55[c]	0.002	0.546
Total EE intake	14.28 ± 2.28[a]	58.60 ± 4.03[c]	33.14 ± 11.53[b]	41.76 ± 2.85[bc]	0.049	0.010
Total CF intake	188.38 ± 38.80	212.71 ± 14.65	140.37 ± 54.80	223.11 ± 15.22	0.805	0.322
Trial II (post-weaning)	CON11	GR14	GR16	GR18	Linear	Quadratic
DMI of Napier grass	561.35 ± 13.03	-	-	-	-	-
DMI of commercial grower pellet	633.57 ± 15.54	-	-	-	-	-
Total DMI	1194.92 ± 27.70[a]	1455 ± 86.46[ab]	1252.15 ± 22.43[a]	1685.85 ± 68.79[b]	0.025	0.429
Total ash intake	60.02 ± 1.24	74.52 ± 4.43	58.22 ± 10.25	71.65 ± 2.92	0.437	0.919
Total OM intake	1130.62 ± 23.43[a]	1380.87 ± 82.03[ab]	1193.92 ± 210.18[a]	1614.21 ± 65.86[b]	0.019	0.431
Total CP intake	144.70 ± 3.08[a]	196.91 ± 11.70[a]	194.21 ± 34.19[a]	297.05 ± 12.12[b]	0.000	0.158
Total EE intake	46.70 ± 1.01[b]	44.24 ± 2.63[b]	30.05 ± 5.29[a]	39.11 ± 1.60[b]	0.013	0.065
Total CF intake	350.70 ± 7.14[a]	443.02 ± 26.32[ab]	362.50 ± 63.81[ab]	462.09 ± 18.85[b]	0.100	0.911

[a,b,c]Different superscripts within the same row indicate significant differences ($P < 0.05$)

DMI dry matter intake, *OM* organic matter, *CP* crude protein, *EE* ether extract, *CF* crude fibre

CON14 control diet at 14% of CP, *CF16* creep feed at 16% of CP, *CF18* creep feed at 18% of CP, *CF20* creep feed at 20% of CP, *CON11* control diet at 11% of CP, *GR14* grower ration at 14% of CP, *GR16* grower ration at 16% of CP, *GR18* grower ration at 18% of CP

Table 5 Growth performance of pre- and post-weaning Dorper lambs

Parameters	Treatment groups (mean ± standard error)				*P* value	
Trial I (pre-weaning)	CON14	CF16	CF18	CF20	Linear	Quadratic
Initial body weight (kg)	5.33 ± 0.60	5.60 ± 0.37	5.67 ± 0.60	6.30 ± 0.41	0.535	0.747
Final body weight (kg)	20.67 ± 0.67^{a}	22.60 ± 0.98^{ab}	25.00 ± 1.00^{bc}	25.90 ± 0.75^{c}	0.001	0.589
ADG (g/day)	196.58 ± 2.14^{a}	217.95 ± 14.19^{ab}	247.86 ± 5.65^{b}	251.28 ± 12.06^{b}	0.005	0.490
RFI	−0.04 ± 0.01	0.09 ± 0.04	−0.21 ± 0.01	0.06 ± 0.01	0.994	0.528
RWG	−0.000 ± 0.001	0.002 ± 0.001	−0.002 ± 0.001	−0.001 ± 0.001	0.808	0.870
RIG	0.04 ± 0.01	−0.09 ± 0.01	0.20 ± 0.001	−0.06 ± 0.003	0.983	0.511
Trial II (post-weaning)	CON11	GR14	GR16	GR18	Linear	Quadratic
Initial body weight (kg)	23.67 ± 0.33^{a}	24.00 ± 1.38^{a}	27.00 ± 1.53^{ab}	28.50 ± 1.20^{b}	0.013	0.673
Final body weight (kg)	27.33 ± 0.67^{a}	30.20 ± 1.83^{a}	36.00 ± 1.53^{b}	34.40 ± 1.83^{ab}	0.006	0.246
ADG (g/day)	43.14 ± 10.38^{a}	72.94 ± 5.76^{ab}	105.88 ± 17.97^{b}	69.41 ± 13.21^{ab}	0.064	0.019
RFI	-0.10 ± 0.04^{ab}	0.08 ± 0.03^{b}	-0.30 ± 0.23^{a}	0.16 ± 0.01^{b}	0.348	0.152
RWG	−0.007 ± 0.007	0.010 ± 0.004	0.013 ± 0.007	−0.013 ± 0.008	0.746	0.039
RIG	0.09 ± 0.05^{b}	-0.07 ± 0.03^{a}	0.31 ± 0.21^{c}	-0.17 ± 0.02^{a}	0.305	0.085

[a,b]Different superscripts within the same row indicate significant differences ($P < 0.05$)

ADG average daily gain, *RFI* residual feed intake, *RWG* residual body weight gain, *RIG* residual intake and body weight gain

CON14 control diet at 14% of CP, *CF16* creep feed at 16% of CP, *CF18* creep feed at 18% of CP, *CF20* creep feed at 20% of CP, *CON11* control diet at 11% of CP, *GR14* grower ration at 14% of CP, *GR16* grower ration at 16% of CP, *GR18* grower ration at 18% of CP

lambs fed on a diet containing CP level at 16%, 18% and 20% in CF16, CF18 and CF20 were not affected significantly ($P > 0.05$). Besides, varying CP levels did not result in linear and quadratic effects of RFI, RWG and RIG.

In Table 5 also, the effect of varying CP levels in grower ration resulted in the linear increase of final body weight of post-weaning lambs. The final body weight of post-weaning lambs in GR16 (36 kg) was significantly ($P < 0.05$) higher than those in CON11 (27.33 kg) and GR14 (30.20 kg). However, there were quadratic effects of varying CP levels on ADG of post-weaning lambs. The ADG was decreased when fed on a diet containing 18% CP (GR18). In general, the RWG and RIG were found non-significant ($P > 0.05$) in all treatments.

Table 6 shows the nutrient digestibility and N balanced of post-weaning lambs. The increase of CP level from 11 to 18% had resulted in linear and quadratic increases in nutrient digestibility. The ash, CF and ADF digestibility were increased when lambs fed with CP level up to 16%, but it was then decreased when the CP level was 18% CP. The increased CP level in the diet resulted in a significant increase of CP digestibility. However, no significant ($P > 0.05$) differences were observed in CP digestibility (%) between GR14 (75.18), GR16 (81.39) and GR18 (81.35). Besides, N intake and N retained were also increased linearly as CP in the diet was increased from 11 to 18%. The N retained of lambs fed on GR14 (20.07), GR16 (22.22) and GR18 (25.78) was significantly ($P < 0.05$) higher than those fed with CON11 diet (5.41).

Discussion

The present finding shows that different levels of CP could significantly affect the feed intake, ADG and digestibility of Dorper lambs. The pre-weaning lambs fed with a high CP level at 20% had higher DMI than the control group at 14% CP, leading to high ADG. It was supported by Sultan et al. (2010) who reported that increasing CP level from 12 to 14% increased the DMI, leading to a significant increase of N intake from 22.2 to 28.0 g/day. In addition, the increase of CP level facilitated ruminal activity, resulting in an increase of DMI (Mutsvangwa et al. 2016). Besides, Vosoogi-poostindoz et al. (2014) reported that increasing CP level from 16 to 18% in pre-weaning diets led to a significant increase in feed intake at 490 g/day and 541 g/day, respectively. Similarly, the present finding showed that DMI of pre-weaning lambs increased linearly with the increasing CP level (Table 4), which also increased ADG linearly (Table 5).

The increased ADG obtained in the pre-weaning lambs fed with different CP levels of diets may be attributed to the increased amount of protein and amino acid available in the small intestine, where the protein and glucose ingested through the small intestine are more efficient resulting in better ruminal fermentation (Rocha et al. 2004). High CP in diet was absorbed in the small intestine, which clarified the high ADG and better feed efficiency. However, in another study, it was suggested that

Table 6 Nutrient digestibility and nitrogen balanced of post-weaning Dorper lambs

Parameters	Treatment groups (mean ± standard error)				*P* value	
	Control	GR14	GR16	GR18	Linear	Quadratic
DMI (kg/day)	0.85 ± 0.09[a]	1.40 ± 0.001[b]	1.33 ± 0.14[b]	1.33 ± 0.05[b]	0.009	0.014
Digestibility (%)						
DM	63.41 ± 3.02[a]	73.29 ± 2.39[b]	75.06 ± 0.87[b]	74.19 ± 2.90[b]	0.014	0.059
Ash	26.08 ± 5.42[a]	59.42 ± 4.20[c]	57.14 ± 1.43[bc]	43.38 ± 5.62[b]	0.039	0.001
OM	65.36 ± 2.90[a]	74.04 ± 2.30[b]	75.94 ± 0.84[b]	75.55 ± 2.78[b]	0.015	0.090
CP	68.76 ± 3.88[a]	75.18 ± 3.24[ab]	81.39 ± 2.40[b]	81.35 ± 1.64[b]	0.010	0.300
EE	93.97 ± 1.52	94.90 ± 0.78	94.03 ± 0.63	90.87 ± 1.77	0.111	0.145
CF	51.26 ± 3.29[a]	68.76 ± 4.80[b]	68.50 ± 1.06[b]	62.86 ± 5.52[ab]	0.093	0.021
ADF	58.39 ± 5.14[a]	71.69 ± 2.05[b]	71.08 ± 1.63[b]	65.54 ± 3.54[ab]	0.206	0.024
NDF	61.90 ± 3.26	72.05 ± 1.85	72.08 ± 0.98	69.33 ± 4.43	0.128	0.059
NFE	69.54 ± 3.02	72.97 ± 1.08	73.50 ± 0.83	73.59 ± 3.02	0.242	0.477
TDN	69.48 ± 2.65	72.76 ± 1.66	72.34 ± 1.05	70.78 ± 3.06	0.738	0.314
N balanced						
Faeces (kg DM/d)	0.31 ± 0.02	0.37 ± 0.03	0.33 ± 0.05	0.35 ± 0.05	0.699	0.508
Urine (L/d)	0.35 ± 0.09[a]	0.69 ± 0.04[b]	0.59 ± 0.10a[b]	0.59 ± 0.04[ab]	0.098	0.045
N content in faeces (%)	1.79 ± 0.14	2..00 ± 0.10	1.84 ± 0.18	2.05 ± 0.05	0.326	0.998
N content in urine (%)	10.25 ± 1.71	9.34 ± 1.39	12.06 ± 1.04	13.24 ± 1.28	0.094	0.470
N intake (g/day)	18.01 ± 1.78[a]	30.35 ± 0.21[b]	32.98 ± 3.55[b]	37.44 ± 1.47[b]	0.000	0.100
N faecal (g/day)	5.49 ± 0.20	7.52 ± 0.94	6.30 ± 1.40	7.02 ± 0.88	0.451	0.510
N urinary (g/day)	7.12 ± 2.43	2.75 ± 0.32	4.46 ± 0.85	4.63 ± 0.44	0.357	0.123
N retained (g/day)	5.41 ± 4.22[a]	20.07 ± 0.87[b]	22.22 ± 2.89[b]	25.78 ± 0.87[b]	0.001	0.068

[a,b,c]Different superscripts within the same row indicate significant differences ($P < 0.05$)

DM dry matter, *OM* organic matter, *CP* crude protein, *EE* ether extract, *CF* crude fibre, *ADF* acid detergent fibre, *NDF* neutral detergent fibre *CON11* control diet at 11% of CP, *GR14* grower ration at 14% of CP, *CF16* grower ration at 16% of CP, *GR18* grower ration at 18% of CP

diets containing 22% and 23.7% CP were sufficient to meet the requirement of lambs, whereas 16% CP was inadequate for lamb growth (Rocha et al. 2004). Besides, the present finding was supported by a previous study which found that CP level < 14% may cause slow growth (Rios-Rincon et al. 2014). These factors may explain the relatively good correlation between CP, ADG and DMI. These findings further support the previous study who reported that better ADG in lambs fed higher CP due to higher DMI and nutrient intake (Xu et al. 2017). In contrast to the current finding, Kaya et al. (2009) reported that lamb fed with 13% and 16% CP diets did not cause a significant difference in DMI and ADG. The present finding revealed that pre-weaning lambs fed with 16%, 18% and 20% CP levels in diet showed no significant difference of ADG, suggesting feed containing 16% CP met the requirement of pre-weaning Dorper lambs. A study in post-weaning lambs proved no significant result when feeding 14%, 16% and 18% CP indicating that 14% CP level in post-weaning diet was sufficient to improve ADG.

Although the ADG of pre-weaning lambs increased linearly with the increase of CP levels in the current finding, there was no significant difference between the CP levels of 16%, 18% and 20% ($P > 0.05$). Kioumarsi et al. (2008) reported that protein level increased from 12 to 14%, ADG increased too, but DMI remains unchanged. Increasing CP level resulted in the elevation in growth rate, feed intake and blood nitrogen concentration. However, Prima et al. (2019) reported that lambs fed with 14%, 16% and 18% CP did not significantly affect ADG. Hence, the CP level up to 18% may not affect animal productivity, as high CP content is not balanced with energy content in the feed. The dietary effect on growth performance was mainly due to energy concentration rather than the level of CP. Slow growth rate and low feed efficiency commonly lead to increase production costs (Rios-Rincon et al. 2014).

A previous study suggested that as protein supply over the requirement, energy becomes limiting for growth and the animals are no longer respond to additional intakes of protein (Titi et al. 2000). Besides, Ruiz-Nuno et al. (2009) claimed that different protein levels had a minor effect on lamb performance in terms of wool or hair sheep when finishing diets containing more than 14% of CP, while Titi et al. (2000) demonstrated that optimum level of dietary protein was 16%. The present finding indicated that varying dietary CP levels had a significant effect on ADG of pre-weaning Dorper lambs. According to the previous study, early creep feeding had a positive impact on body weight gain and facilitated the transition from monogastric to a ruminant, buffering the weight loss of the lambs after the milk production peak of their dams (Martinez et al. 2015). In addition, solid feed in the pre-weaning lambs at an early stage increased proliferation and prevented apoptosis of ruminal epithelial cells, as well as promoting volatile fatty acid metabolism in the ruminal epithelium (Sun et al. 2018). The reasonable forage to concentrate ration, stable feed value and proper feed moisture of creep feed diet could increase rumen microbial activity and protein synthesis rate, maintaining normal fermentation, digestion, absorption and metabolic activities resulting in better growth performance (Xu et al. 2017).

In the present study, creep feed consisted of concentrate, premix, salt and Napier grass with a reasonable grass length at 2–4 cm was mixed for 3–5 min. The proper feed moisture ensured nutritional equilibrium and good feed palatability compared to the control diet, leading to higher nutrient intake. In the opposite finding by Beauchemin et al. (1995), it showed that lambs fed with 18% CP diet had higher CP intake compared to those fed with 15% CP diet, whereas ADG of lambs fed with 18% CP in present finding was not significantly different compared to those fed with 16% CP.

Besides, increasing CP level from 14 to 20% did not significantly affect the RFI, RWG and RIG of pre-weaning lambs. However, negative RFI in CON14 and CF18 suggested that the lambs consumed less feed than the estimated feed to its body weight and weight gain. It was established that the most efficient animals have low RFI. The RFI acts as a tool to measure the profitability in the meat production industry (Paula et al. 2013). For post-weaning lambs, the RFI of lambs fed with 11% CP (CON11) and 16% CP (GR16) were negative. In general, pre- and post-weaning lambs fed with 16% CP and 14% CP respectively were the most efficient in terms of intake and body weight gain. However, the opposite finding by Urbano et al. (2017) did not find significant difference in feeding 15% and 20% CP on ADG of pre-weaning Suffolk lambs. Another study on post-weaning lambs revealed an opposite finding as lambs fed with 18% CP had significantly higher ADG than those fed with 16% CP (Dabiri, 2016). The RFI was influenced by ingesting behaviour, feed intake, feed digestion with associated energy use, feed metabolism and thermoregulation. The RFI takes into account the energy requirements for maintenance and production and is more sensitive to variations in the individual energy efficiency of the animal (Singh et al. 2019).

High CP in diet stimulated ruminal microbial protein synthesis as well as ruminal fermentation and subsequently increased the digestibility of feed (Sultan et al. 2010). On the other hand, the inclusion of molasses, rice bran and grains in the growing ration in the form of TMR had improved the efficiency of microbial synthesis in the digestive system of lambs (Nejad et al. 2014). A finding by Kaya et al. (2009) showed that post-weaning lambs fed 16% had significantly higher CP digestibility. In the present finding, all treatments showed DM digestibility > 55% which considered acceptable. Norhayati et al. (2020) stated that DM digestibility < 55% was poor. Besides, significantly higher DM digestibility in lambs fed 14% (GR14), 16% (GR16) and 18% (GR18) CP than those fed with 11% CP (CON11) were due to significantly higher DMI of these treatments.

Besides, all treatments had shown positive N retention. Increased CP level from 11 to 18% results in linear increase of N retention. This positive N retention indicated the recycling of N through the ruminal wall and saliva for microbial synthesis (Nejad et al. 2014). Besides, higher N retention indicated a decreased proportion of N loss in the urine (Foster et al. 2009).

In conclusion, varying CP levels had a significant effect on growth performance, nutrient intake and digestibility of Dorper lambs in Malaysia. In overall finding, creep feed containing 16% CP was found sufficient to enhance the pre-weaning performance of Dorper lambs, whereas minimum CP level at 14% was sufficient to enhance post-weaning performances of Dorper lambs. The additional CP level over these requirements did not improve the growth performance of lambs. The finding of this study rejected the tested hypothesis as the additional CP level over 18%, and 16% for pre- and post-weaning lambs respectively, did not improve the growth performance of Dorper lambs. Hence, the present finding suggested that the optimum CP level for pre- and post-weaning Dorper lambs in Malaysia was 16% and 14%, respectively.

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Author contribution NDR and KM conceived and designed research. MP conducted experiments and analysed data. MP wrote the original draft preparation. NDR, KM, MMR, MAKG and MB reviewed and revised the manuscript draft. KM, NDR and MAKGK supervised the research work. NDR contributed the materials and reagents. All authors read and approved the manuscript.

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Data availability All data generated or analysed during this study are included in this published article (and its supplementary information files).

Declarations

Ethics approval The study protocol and procedure were approved by the Institutional Animal Care and Use Committee of Universiti Malaysia Kelantan (UMK/FPV/ACUE/PG/2/2019).

Consent to participate All authors have consented to participate in this article.

Consent for publication The participant has consented to the submission of articles to the journal.

Statement of animal rights The study protocol and procedure were approved by the Institutional Animal Care and Use Committee of Universiti Malaysia Kelantan (UMK/FPV/ACUE/PG/2/2019).

Competing interests The authors declare no competing interests.

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