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Cost-effectiveness of Total Mixed Ration with Varying Crude Protein Levels for Feeding Dorper Lambs for Human Consumption

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Abstract:
The demand for food consumption had increased by 60% due to the increase of human population, resulting in an increasing demand for sheep meat. High cost of imported feed had restricted the growth of the sheep industry. Hence, the objective of this study was to evaluate the cost-effectiveness of feeding total mixed ration (TMR) in the form of creep feed (CF) and growing ration (GR) to Dorper lambs compared to the control (CON) group fed with farm routine diet consisted of Napier grass and commercial pellet. Two (2) experimental phases were conducted, i.e., Phase I (CF) and Phase II (GR), which consisted of twenty (20) Dorper lambs with five (5) lambs in each group. The CF and GR consisted of constant metabolize energy (ME) (11 MJ/kg DM ME). The crude protein (CP) (%) in CF was varied at 14, 16, 18 and 20 for CON 14, CF 16, CF 18 and CF 20 respectively, whereas the CP (%) in GR was varied at 11, 14, 16 and 18 for CON 11, GR 14, GR 16 and GR 18 respectively. The cost of feed/kg gain (RM/kg) of CON 14 (1.63) and CF 18 (1.97) was significantly lowered ($p<0.05$) than CF 20 (3.35) whereas, GR 16 (8.94) was significantly lowered ($p<0.05$) than CON 11 (22.92) and GR 18 (23.99). This finding revealed that feeding local feed ingredients in TMR form, resulting in low feeding cost and subsequently higher economic returns. It can be concluded that feeding 18% CP (CF 18) and 16% CP (GR 16) were efficient to enhance the growth performance of pre-and post-weaning Dorper lambs respectively.

Keywords: Creep feed; Dorper lambs; Growing ration; Total mixed ration

1. Introduction

A total mixed ration (TMR), also known as a complete ration, is produced by combining feed ingredients at particular weights to produce a nutritionally balanced ration that provides adequate nutrients for optimum performance and animal demands. The TMR feeding provides animals with the same feeding mixture [1]. It is also a feeding solution that utilizes feed components like forages, cereals, and nutritional supplements [2]. The TMR-fed animals consumed a predetermined amount of forage and concentrate needed for production and health. Furthermore, selective feed consumption is reduced as the TMR consisted of a combination of forages and grains where the animals consumed together instead of separate feeding of forage and grains [3]. The TMR feeding is also cost-effective as it uses a variety of agro-industrial by-products and farm-grown forages [4].

Pasture, crop residues, forage crops, agro-industrial by-products, and non-traditional feeds are the most common feed resources for sheep [5]. The availability of agro-industrial by-products and crop residues, particularly from the oil palm and rice industries will influence local feed resources. Thus, increasing domestic feed production will result in Malaysia's more sustainable ruminant industry [6].

The palm kernel cake (PKC) is a by-product of palm kernel oil extraction via solvent (hexane) extraction of ground palm kernels [7]. It serves as a source of fatty acids such as lauric, myristic, oleic, palmitic, stearic, and linoleic, raising gonadotropin-releasing hormone (GnRH) pulses and improving reproductive performance [8]. It is also a low-cost source of high-quality ruminant feed that contains 16-20% protein [9]. Copra meal is a cake made from coconut oil extracted from the coconut flesh using the expeller method [10]. The difference in nutrient composition of copra meal is due to variations in residual oil concentration. A common issue with copra meal is its quality as it can be contaminated with aflatoxin, which can cause rancidity, thus lowering feed intake and efficiency [11].

Rice bran is a high-energy, protein-rich source of minerals and vitamins. Rice bran was composed of bran and polishing and the embryo, endosperm, inner and outer bran layers [12]. Rice bran contains 11.5% crude protein (CP), 2100 kcal metabolize energy (ME), calcium (Ca) and phosphorus (P) which are necessary for growth [13]. Overall, rice bran provides rumen with a low-cost energy source for efficient nutrient utilisation and microbial protein synthesis [14]. Maize is also a significant energy source in livestock diets [15]. In comparison to other feeds, maize has a low protein content. It also contains essential minerals and vitamins for animals [16]. Wet milling of maize grain yields a variety of maize by-products such as maize gluten meal, maize gluten feed, maize germ meal, and condensed fermented maize extractives [17].

Molasses are viscous, dark liquids formed by repeated crystallisation from the sugar preparation technique. It contains 60-63% sucrose, 3-5% reducing sugars, and 3-5% trace minerals [18]. It also has a high energy and protein of about 5%. It is highly palatable and beneficial in stimulating bacteria multiplication in the rumen, which aids in the digestion of fibrous feed. When mixed with chopped grass, hay, or straws, the recommended inclusion level of molasses in the diet is 2% [19]. Feeding creep feed (CF) and growing ration (GR) are essential for meeting the nutritional needs of pre-and post-weaning animals. Creep feeding is supplementing nutrition to improve offspring performance during the pre-weaning period. The approach entails supplementing offspring's diets [20]. In contrast, the GR in TMR form will ensure nutrient demands are met, resulting in an optimum performance at growing stages to achieve the desired production level [21].

Due to high feeding costs as feed ingredients are imported, this has recently become a significant concern. Despite the fact that natural pastures and crop residues were abundantly produced, their use for livestock feeding has been hampered by economic issues. The primary ingredients in the commercially prepared feed are imported feed grains such as maize, soybeans, sorghum, oats, and barley. As a result, most feed ingredients must be imported, resulting in year-round unsustainable meat production. Malaysia imports more than 70% of the raw materials used in the animal feed industry each year, including 2000 tonnes of corn and 1000 tonnes of soybean meal. Malaysian imports of animal feed are estimated to be worth RM 6.7 billion [22].

In Malaysia, the sheep population increased by 19% between 2010 and 2015, rising from 123 475 to 147 033 heads. However, the population fell to 138 479 heads (5.8%) and 137 872 heads (0.4%) in 2016 and 2017, respectively. The sheep population increased by 0.17% in 2018 to 138 111 heads [23]. More than 7000 tonnes of sheep meat were produced during this period. In 2050, the global human population is expected to reach 9.1 billion. As a result, food demand will rise by 60%, resulting in increased demand for sheep meat [24].

As a result, Dorper sheep were imported from South Africa to meet 30% of the country's meat production demand. In 2009 and 2011, 3000 and 4680 heads of Dorper sheep were imported, respectively, to produce a high-value Dorper breed that is well-suited to the local environmental conditions [25]. Developing practical and cost-effective feeds becomes a concern when using local forages, crop residues, and agricultural by-products as ruminant feeds [26]. Various studies have been conducted to improve the feeding value of local ingredients in feed rations, including availability, nutritional value, the optimum level of inclusion, and treatment methods [6]. However, there has been little research in Malaysia on optimising local ingredients in the form of TMR for feeding sheep. Furthermore, current sheep feeding practices in Malaysia adhere to the international feeding standards established by the United States (National Research Council) and the United Kingdom (Agriculture and Food Research Council). Due to differences in feed ingredients and nutritional quality, environmental conditions (tropical vs temperate), animal breeds, and genetics, international feeding standards are not always appropriate for use locally [27]. As a result, nutritional requirements, particularly crude protein (CP) of Dorper sheep raised in Malaysia may differ from the established feeding standard.

Hence, it is critical to determine the CP requirement of Dorper sheep by utilising local feed resources to produce cost-effective feeding methods to improve weaning and growth performance. The aims of this study were to determine the cost-effectiveness of feeding total mixed ration (TMR) to Dorper lambs in the form of creep feed (CF) and growing ration (GR) with varying CP levels.

2. Materials and Methods

2.1 Ethics statements

The study protocols, procedures and consent form were approved by the Institutional Animal Care and Use Committee of Universiti Malaysia Kelantan (UMK/FPV/ACUE/PG/2/2019).

2.2 Study area and experimental animals

This study was conducted at Agropolitan Besut-Setiu, located in Terengganu. There were two phases conducted in this study. Phase I consisted of twenty (20) pre-weaning Dorper lambs at 7 days old with a mean initial body weight of 2.91±0.07 kg. Phase I was conducted from day 7 to day 84 of the feeding trial. Phase II was a continuation of Phase I which was conducted from day 85 to day 180 of the feeding trial. Figure 1 shows the Dorper lambs during the feeding trial.

Figure 1. Dorper lambs

2.3 Experimental design

All animals were randomly allocated into four (4) groups, with five (5) animals in each group based on the initial body weight, according to the Randomized Complete Block Design (RCBD). The lambs were penned individually in pens measuring 1.2 m x 1.5 m with their dams in separate pens. The lambs had access to the mother milk during the pre-weaning period.

2.4 Experimental diets and treatments

In Phase, I, lambs at pre-weaning stages (day 7 to day 84) in the control (CON) group were fed with Napier grass and commercial creep pellet (CON 14) while the treatments consisted of creep feed (CF), i.e., CF 16, CF 18 and CF 20. In Phase II, lambs at post-weaning stages (day 85 to day 180) were fed Napier grass and a commercial grower pellet (CON 11). In contrast, the treatment groups were fed with growing ration (GR), i.e., GR 14, GR 16 and GR 18.

2.5 Preparation of creep feed and growing ration

The TMR was made up of forage (Napier grass) and grains (PKC, soybean meal, soyhull, corn meal, molasses, mineral premix and salt). The TMR was mixed using a cement mixer. The ingredients were weighed in accordance with the formulation shown in Table 1.

Table 1. Formulation of creep feed and growing ration

Ingredients	**Formulation (%)**							
	CON 14	**CF 16**	**CF 18**	**CF 20**	**CON 11**	**GR 14**	**GR 16**	**GR 18**
Napier grass	40	40	40	40	60	60	60	60
Copra cake	0	20.5	18.4	18.4	0	13.7	6.8	10.5
PKC	0	0	0	0	0	3.7	3.7	0
Soybean meal	0	10.5	16.9	23.5	0	9.9	16.8	23.3
Corn meal	0	0	0	0	0	5.5	5.5	4
Soya hull	0	17.8	16.8	12.9	0	5	5	0
Rice bran	0	9	5.6	2	0	0	0	0
Molasses	0	2	2.1	3	0	0	0	0
Mineral premix	0	0.1	0.1	0.1	0	2	2	2
Salt	0	0.1	0.1	0.1	0	0.1	0.1	0.1
Creep pellet	60	0	0	0	0	0.1	0.1	0.1
Grower pellet	0	0	0	0	40	0	0	0

The first mixing step involves combining forage with mineral premix and salt (Figure 2). The forages were chopped before being added to the mixer. The ingredients were thoroughly combined. Other grains, such as soybean meal, soy hull, copra cake, rice bran, and PKC, were added. Finally, molasses liquid feed was added to the mixture. To ensure homogeneous mixing, the mixture was allowed to mix for 5 minutes.

(a) (b)

(c)

Figure 2. (a) Chopping of Napier grass using chopper, (b) Mixing of TMR using cement mixer and (c) Well mixed forage and concentrate

2.6 Chemical analysis of diets

The feed ingredients, control and formulated diet were analyzed for dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE) and ash according to AOAC (1997) [28]. The DM was determined by drying the sample in a forced-air oven for 24 hours at 105˚C, whereas ash was determined by incinerating the sample at 600˚C for 4 hours in a furnace. The Kjeldahl method determined the CP, which involves sample digestion in concentrated sulphuric acid at 400˚C, followed by distillation with sodium hydroxide solution and titration against the hydrochloric acid. The EE was determined by extracting the sample with petroleum ether. The CF was determined by washing the sample with sulphuric acid and sodium hydroxide in the Gerhardt Fibretherm system.

2.7 Calculation of feeding cost and cost analysis

The feeding cost was calculated based on the total DMI, at which the total dry matter intake (DMI) throughout the feeding trial times with the cost of 1 kg feed, as shown in Equation 1.

$$Cost\ of\ total\ DMI\ (RM) = Total\ DMI\ (kg)\ x\ Feed\ cost(RM) \qquad (1)$$

The cost analysis was determined as cost/kg gain (RM/kg) and calculated, as shown in Equation 2. The cost analysis excludes the cost of labour, electricity and other related equipment and utensils.

$$Cost\ per\ kg\ gain\ \left(\frac{RM}{kg}\right) = \frac{Cost\ of\ total\ DMI\ (RM)}{Total\ weight\ gain\ (kg)} \qquad (2)$$

2.8 Data analysis

The data of cost analysis of control and formulated diet were analyzed by one-way Analysis of Variance (ANOVA) using Statistical Package of Social Science (SPSS) version 25 (Inc., Chicago, IL, USA). If there were significant differences ($p<0.05$) between different diets, the Duncan Multiple Range Test further analysed the data.

3. Results and Discussion

Table 2 shows the chemical composition of the feed ingredients and the diets. The DM of Napier grass (19%) was the lowest followed by molasses (72%). Other feed ingredients contained >85% DM. The ash of Napier grass, PKC, soyhull, copra cake, molasses and soybean meal ranged from 4% to 9%. However, the ash content of salt, mineral premix and rice bran was the highest which at 98%, 73% and 11% respectively. Besides, the CP in soybean meal was the highest at 47%, followed by copra cake (17%), soyhull (16%), PKC (16%) and rice bran (12%). Napier grass and corn meal has a low CP ranged from 7% to 8%. The EE contained in copra cake was the highest at 9%, whereas EE in other feedstuffs ranged between 1% to 7%, except for molasses, mineral premix and salt with 0% EE. For the CF, the highest content was found in Napier grass (39%), followed by soyhull and copra cake, which contained 27% CF. Rice bran (12%) and soybean meal (5%) contained low CF, meanwhile CF was not present in molasses, mineral premix and salt. The DM, ash and EE of formulated CF showed a small difference. The formulated CF also contained 61-62% DM, 6-8% ash and 5-6% EE. For GR, the ash and EE content in formulated GR were 4-5% and 2-3%, respectively. Besides, CF was ranged between 27-30%.

Table 2. Chemical composition of feed ingredients and diets

Feed	DM (%)	Ash (%)	CP (%)	EE (%)	CF (%)
Feed ingredients					
Napier grass	18.80±0.15	5.38±0.09	8.06±0.11	1.95±0.02	39.01±1.02
Rice bran	90.09±0.04	11.14±0.05	12.13±0.07	6.56±0.17	12.17±0.43
PKC	90.33±0.03	4.36±0.05	15.57±0.05	1.37±0.01	39.05±0.55
Corn meal	87.37±0.02	1.38±0.02	6.98±0.04	4.31±0.08	2.52±0.22
Soybean meal	89.47±0.03	7.35±0.30	45.68±0.08	2.20±0.40	4.81±0.13
Soyhull	90.16±0.02	9.44±0.07	16.07±0.45	6.09±0.05	26.89±0.85
Copra cake	92.34±0.01	6.85±0.03	16.89±0.38	9.31±0.14	26.51±0.14
Molasses	72.03±0.09	3.70±0.01	4.49±0.14	0	0
Mineral premix	94.29±0.04	72.63±1.66	0	0	0
Salt	98.78±0.04	97.98±0.11	0	0	0
Control diet					
Creep pellet	87.68±0.03	4.54±0.01	18.26±0.27	2.84±0.09	21.88±0.51
Grower pellet	90.65±0.04	4.74±0.07	15.78±0.08	5.67±0.11	20.99±1.13
Formulated diet					
CF 16	61.63±0.55	7.81±0.15	16.17±0.51	6.76±2.24	24.54±0.15
CF 18	61.53±0.87	7.43±0.19	18.17±0.15	4.87±0.12	20.63±0.45
CF 20	61.32±0.36	6.39±0.37	20.12±0.62	3.94±0.26	21.05±1.05
GR 14	47.08±0.40	5.12±0.01	13.53±0.38	3.04±0.05	30.44±0.14
GR 16	46.88±0.56	4.65±0.02	15.51±0.20	2.40±0.13	28.95±0.20
GR 18	46.95±0.20	4.25±0.01	17.62±0.08	2.32±0.10	27.41±0.21

As shown in Table 3, the production costs of the control diet and creep feed for CON 14, CF 16, CF 18, and CF 20 were RM 0.79, 0.73, RM 0.83, and RM 0.93, respectively. The lowest cost formulation is CF 16, which has a lower inclusion of soybean meal than other formulations as soybean meal is an expensive protein source. Creep feed with increased inclusion of protein sources in its formulation contributed to its higher price. However, due to the high cost of commercial creep pellet, the control diet was more expensive than CF 16. Besides, CON 11, GR 14, GR 16, and GR 18 had the lowest production costs (RM) at 0.50, 0.57, 0.67, and 0.77, respectively.

Table 3. Production cost of a control diet, creep feed (CF) and growing ration (GR)

Ingredients	**Cost (RM/ kg)**	**CON 14**	**CF 16**	**CF 18**	**CF 20**	**CON 11**	**GR 14**	**GR 16**	**GR 18**
Napier grass	0.10	0.04	0.04	0.04	0.04	0.06	0.06	0.06	0.06
Rice bran	0.70	-	0.06	0.04	0.01				
PKC	0.60	-	-	-	-	-	0.02	0.02	-
Corn meal	0.95	-	-	-	-	-	0.05	0.05	0.04
Soybean meal	2.30	-	0.24	0.39	0.54	-	0.23	0.39	0.54
Soy hull	0.95	-	0.17	0.16	0.12	-	0.05	0.05	-
Copra cake	0.90	-	0.18	0.17	0.17	-	0.12	0.06	0.09
Molasses	1.30	-	0.03	0.03	0.04	-	0.03	0.03	0.03
Mineral vitamin premix	6.85	-	0.007	0.007	0.007	-	0.007	0.007	0.007
Salt	0.65	-	0.001	0.001	0.001	-	0.001	0.001	0.001
Creep pellet	1.25	0.75	-	-	-				
Grower pellet	-	-	-	-	-	0.44	-	-	-
Total cost+	-	0.79	0.73	0.83	0.93	0.50	0.57	0.67	0.77

Table 4 depicts the cost analysis in Phase I and II. The total DM consumed, feed cost, total weight gain, and feed cost/kg gain increased linearly (p<0.05) as the CP level in the diet increased. The total DM consumed (kg) increased linearly (p<0.05) with increasing CP levels in the diet in the following order: CF 20 (82.67) > CF 16 (67.61) > CF 18 (53.07) > CON 14 (41.51). The cost of feeding lambs (RM) in CF 20 (76.89) was significantly higher (p<0.05) than in CON 14 (29.19), CF 16 (49.36), and CF 18 (44.05), but there was no significant difference ($p>0.05$) between CON 14, CF 16, and CF 18. Total weight gain (kg) in CF 16 (19.70) was also significantly lower ($p<0.05$) than in CF 20, but not significantly different ($p>0.05$) from CON 14 and CF 18. Total weight gain increased linearly with increased CP levels in the diet ($p<0.05$).

In general, the cost of feed/kg gain of pre-weaning Dorper lambs in Trial I was statistically significant ($p<0.05$) between groups. The CON 14 (1.63) and CF 18 (1.97) had significantly lower feed/kg gain (RM/kg) costs ($p<0.05$) than CF 20. (3.35). The cost of feed/kg gain between CON 14 and CF 16 (2.51), on the other hand, did not differ significantly ($p>0.05$). It was also discovered that increasing the level of CP in the diet caused a linear increase in feed cost/kg gain ($p<0.05$). One of the most important factors in a farmer's ability to maintain economic viability when raising meat sheep is how quickly and efficiently their lambs grow. High growth rates and efficiency reduced the time it takes lambs to reach market weight, lowering labour and feed costs [29]. Concentrate feed, on the other hand, may result in high lamb growth rates, but it also has a higher production cost, and the benefit does not always outweigh the costs [30]. The current finding was consistent with a study conducted by [31], which discovered that different protein levels had a significant effect on feed to gain ratio. According to a study published in [32], increasing the CP level improves feed efficiencies.

In Phase II, the total DM consumed, cost of feeding lambs, total weight gain, and cost of feed/kg gain were all statistically significant (p<0.05). The total DMI (kg) of GR 18 (160.92) was significantly higher ($p<0.05$) than CON 11 (114.30) and GR 16 (114.30). However, there were no significant differences ($p>0.05$) in total DMI between GR 18 and GR 14. (131.66). Furthermore, as the CP level in the diet increased, total DM consumed increased linearly ($p<0.05$).

Furthermore, the cost of feeding lambs (RM) was significantly higher ($p<0.05$) in GR 18 (123.91), followed by GR 16 (80.54), GR 14 (75.05), and CON 11. (72.04). However, there was no statistically significant difference (p>0.05) in the cost of feeding lambs between CON 11, GR 14, and GR 16. Increased CP level in diet had a linear and quadratic effect ($p<0.05$) on lamb feeding cost.

In terms of total weight gain (kg), GR 16 (9.00) had a significantly higher ($p<0.05$) total weight gain than CON 11. (3.67). However, there was no statistically significant difference ($p>0.05$) in total weight gain between GR 14 (6.20), GR 16 (9.00), and GR 18 (5.90). When total weight gain was considered, the most profitable feed was GR 16. Higher economic returns result from higher total weight gain and lower feeding costs. The cost of feed for a 1 kg increase in body weight was RM 8.94 for GR 16, RM 12.13 for GR 14, RM 22.92 for CON 11, and RM 23.99 for GR 18.

Table 4. Cost analysis (Mean±SE) of control and formulated diet in Trial I and Trial II

Trial I – Creep feed Parameters	CON 14	CF 16	CF 18	CF 20	p-value	
					Linear	Quadratic
Trial I – Creep feed						
Total DM consumed (kg)						
- Napier	19.73±1.61	-	-	-		
- Creep pellet	21.77±1.63	-	-	-		
- Creep feed	-	-	-	-		
- Total	41.51±3.22^{a}	67.61±4.65^{ab}	53.07±2.72^{a}	82.67±5.64^{b}	0.020	0.850
Feeding cost (RM)	29.19±2.20^{a}	49.36±3.40^{a}	44.05±7.20^{a}	76.89±5.25^{b}	0.002	0.419
Total weight gain (kg)	17.83±0.60^{a}	19.70±1.07^{ab}	22.17±0.83^{bc}	22.9±0.64^{c}	0.001	0.545
Feed cost/kg gain (RM/kg)	1.63±0.07^{a}	2.51±0.16^{ab}	1.97±0.30^{a}	3.35±0.18^{b}	0.006	0.446
Trial II – Growing ration Parameters	CON 11	GR 14	GR 16	GR 18	p-value	
					Linear	Quadratic
Total DM consumed						
Napier	34.26±2.26	-	-	-	-	-
Creep pellet	51.15±3.47	-	-	-	-	-
Creep feed	-	-	-	-	-	-
Total	114.30±2.37^{a}	131.66±9.71^{ab}	120.21±2.16^{a}	160.92±7.14^{b}	0.025	0.317
Feed cost (RM)	72.04±1.61^{a}	75.05±5.54^{a}	80.54±4.18^{a}	123.91±5.49^{b}	0.000	0.018
Total weight gain (kg)	3.67±0.88^{a}	6.20±0.49^{b}	9.00±1.53^{b}	5.90±1.12^{ab}	0.064	0.019
Feed cost/kg gain (RM/kg)	22.92±6.99^{b}	12.13±0.30^{ab}	8.94±0.57^{a}	23.99±4.07^{b}	0.999	0.005

^{abc} means in the same row with different superscripts are significantly different ($p<0.05$)

4. Conclusion

In conclusion, feeding lambs in CF 18 and CON 14 in Trial I is more profitable than the other groups. The control diet results were attributed to low DMI, which reduced the cost of feeding lambs, whereas, in Trial II, the most profitable feed in terms of cost and benefit in terms of weight gain was those feds with 16% CP, who had the lowest feed cost/kg gain.

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