EVALUATION OF NUTRITIONAL NEEDS, BODY WEIGHT GAIN AND ECONOMIC VIABILITY OF STAGE FEEDING ON KATJANG-BOER CROSSBRED GOATS

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ABSTRACT. Cost of feed is one of the primary stumbling blocks for goat farming in Malaysia. Stage feeding was introduced as a method to formulate feed at minimum cost based on the requirement of different stages of production to improve overall farm productivity. A study was conducted to evaluate 5 feeding rations formulated based on the requirements of different production stages on Katjang-Boer crossbred. Ration formulated of creep feed (CF) for a period of 101d, starter grower (SG) (70d), grower finisher (GF) (98d), flushing feed (FF) (97d) and maintenance feed (MF) (155d) were compared with commercial feed (CCF and CMF) as control. Results showed a significantly higher ($P<0.05$) preweaning bodyweight of 12.83 ± 3.61 kg in CF at 101 days of age. Post weaning also achieved significantly higher body weight ($P<0.05$) of 22.20 ± 2.78 kg and 31.5 ± 4.67 in SG (223 days) and GF (361 days) of age respectively. Feed cost per kg gain obtain in CF (RM5.68), SG (RM9.03) and GF (RM6.57) were lower compared to CCM of RM6.14, RM10.27 and 12.99 respectively. FF showed a significantly higher ($P<0.05$) average daily gain (ADG) of 67.01 ± 14.42 g while MF was able to maintain body weight at minimum cost. Stage feeding proved to be able to meet nutritional needs through significantly higher body weight in CF, SG, GF and FF as well as lower feed cost per kg gain rendering it as a more economical option.

Keywords: stage feeding, Katjang-Boer crossbred, growth performance, bodyweight, feed cost

INTRODUCTION

Self-sufficiency in goat meat has significantly dropped in Malaysia from 15.2% in 2015 to 10.0 % in 2019 and goat population has declined from 431,651 in 2015 to 371,747 in 2019 (DVS, 2020a). One of the challenges of the goat industry in Malaysia is the lack of goat breeder farms due to unavailability of a suitable breed for tropical climate in this country. Therefore, under the 11th Malaysian Development Plan, crossbreeding between Katjang bucks with imported pure bred of South African Boer does was carried out in order to improve adaptability of imported breed (Hifzan *et al*., 2018). However, in order to sustain nutrient requirements for Katjang-Boer crossbred in breeder farms, sufficient energy and protein need to be supplied through feed resources. Therefore, nutrition studies have been carried out to fulfil the nutrient requirement of this breed at the MARDI research centre in Kluang, Johore. This study is crucial due to the fact that nutrition is a major factor in the development of the livestock industry which also consumes up to 70% cost of production (Wan Zahari and Wong, 2009). Lack of nutritional supply leads to suppressed growth (Htoo *et al*., 2015) whereas excessive energy or protein density may lead to suppressed dry matter intake (Zalika *et al*., 2019). In 2018, the cost of imported animal feed in Malaysia reached RM 6.73 billion (DVS, 2020b). The main feed components being imported to this country were soybean meal and corn which were mainly supplied for the non-ruminant subsector of poultry and swine as well as the aquaculture industry (Wan Zahari and Wong, 2009). Due to the high cost of feed, optimization of local resources is crucial, including the usage of crop residues, low quality roughages and various legumes available in the region (Devendra, 1985).

Requirements of goats in tropical regions are affected by climatic environment, animal genotypes as well as lower diets nutritional values (Salah *et al*., 2014). An optimized linear programme that builds feed formulation matrix enables an estimated range of dry matter intake (DMI), energy (Metabolisable energy, ME) and protein (Crude protein, CP) to simulate feeding in goats. These models should suit tropical needs based on nutrient digestion and utilization which are specific for selected breed and available feed material in the region (Kebreab *et al*., 2009). In regions where good quality forages are limited, high quality concentrate feed can be cheaper than feeding high quality forage diets (Marín *et al*., 2012). In Malaysia, preference for extensive systems of farming is declining due to increasing price of lands. Optimization of feeding ration is crucial to stimulate good growth performance in goats. Some of the major agricultural by-products of rice, oil palm and coconut can be incorporated into feeding rations to improve growth performance (Wan Zahari and Wong, 2009). Previous study showed that cost of palm kernel expeller can range from USD 92-237 per tonne (conversion rate of 1 USD to RM 4.34) depending on the region in Peninsular Malaysia (Hazwan *et al*., 2016) and estimate ME of 7 to 12 MJ/kg (Predith *et al.,* 2018; Heuzé *et al*., 2016) with DM degradation up to 69% at 72 hour (Predith *et al*., 2018) among other agricultural by-products. Nutrient value and digestibility of several crops and by-products that are commonly used by local farmers have also been previously reported in several other sources (Devendra, 1985; Yusof *et al*., 1990).

The requirement of energy and protein at different stages of production (maintenance, growth, pregnancy, and lactation) would require different utilisation of feed resources in order to meet nutritional requirements (Sahlu *et al*., 2004). It was found that preweaning management with creep feeding had improved weaning weight (Htoo *et al*., 2015). This is because milk production in dams peaks at 2-3 weeks and declines at 8-10 weeks post-parturition, in which additional nutrition needs to be supplied to preweaning kids after 3 weeks of age (Htoo *et al*., 2015). Risk of preweaning malnutrition is further complicated with dams with twins or triplets (Goetsch *et al*., 2011). Post-weaning requirements are also different due to the inclusion of forages into the diet as well as to meet nutritional requirements based on target growth rate (Kearl, 1984). Breeding generally requires a body condition score (BCS) of 3.5 - 4 (BCS scale of 1 - 5) (Hifzan *et al*., 2012). In this case, a feed formulation for flushing stage prior to breeding cycle would allow improvement of body condition score to improve fertility rate in the goats (Mac Donald *et al*., 2002). Finally, for the Malaysian market, religious festivals particularly for the Malay and Indian ethnic group would require an ideal body weight of 45 - 55 kg (Hifzan *et al*., 2018). Thus, feeding at a maintenance level of nutritional requirement would allow the body weight of the goat to be maintained till the required slaughter period of the religious festival at a minimum cost.

Thus, in order to achieve the needs of different stages of production mentioned, several feed formulations were devised using locally available feed materials at a minimum cost. The objectives of this study are to evaluate nutritional need, body weight and economic viability of stage feeding of 5 types of formulation that were formulated based on the requirement of different production stages: creep feed (pre-weaning, birth to 3 months), starter grower feed (post-weaning, 3 - 7 months), grower finisher feed (post-weaning, 7 - 12 months), flushing feed and maintenance feed on Katjang x Boer goats.

MATERIALS AND METHOD

A least cost feed formulating ration module with solver function was developed using Microsoft Excel programme in ration formulation to meet or achieve the closest to the requirements of Katjang x Boer goats at different stages of production by inserting data of proximate analysis of commonly available raw materials such as palm kernel expeller (PKE), distiller's dried grain with solubles (DDGS), wheat pollard, grain corn, soybean meal, rice hull, molasses, soybean hull, broken rice, skim milk, crude palm oil, limestone, urea and forage (*Bracharia humidicola*) collated by Predith *et al.* (2018) and Yusoff *et al.* (1990). Daily nutrient requirements for different stages of growth of goats were based on Kearl (1984) as presented in Table 1.

Farm practices were referred to published manuals of rearing Savanna goats. This includes farm feeding practices of preweaning, post weaning, flushing prior to breeding and maintenance. (Hifzan *et al.*, 2012). Therefore, formulation and experimentation were carried according to these stages to mimic common farm practices.

Formulations

Pre-weaning stage

A total of 12 Katjang Boer crossbred kids at birth with dams were assigned randomly to 2 treatment groups of formulated creep feed (CF) and commercial dam and kid feed (CCF). They were fed *ad libitum* up to 101 days of age with an average birth weight of 2.1 ± 0.17 kg. Dams were fed 3.5% dry matter intake (DMI) for both treatment groups of 60% forage and 40% concentrate (Kearl, 1984). Dams and kids were dewormed and vaccinated prior to experimentation according to standard farm protocols. Creep feed pens were designed so that kids had free access to creep feed and their dams for milk. Data of bodyweight (BWT) (every 2 weeks) and residual feed (daily) were collected.

Post weaning stage

An additional 12 Katjang-Boer crossbreds were randomly chosen and added to the current 12 pre-weaned kids to make a total of 24 goats. An adaptation period of 62 days was given, and a mix feed of creep formulation (50%) and starter grower formulation (50%) were fed. The same animals were then subjected to the growing phase experimentation. Subsequently, these goats of an average age of 5 and half months with average body weight of 12.8 ± 2.23 kg, 12 males and females, were randomly assigned to two treatment groups of formulated starter grower feed (SG) and CCM. Data of formulated SG feed were collected for 70 days up to an average age of 235 days old. An adaptation period of 26 days was given before proceeding to the next growth stage and animals were fed a mixture of starter grower (50%) and grower finisher (50%). In the following experiment, the same animals were used with an average body weight of 24.0 ± 4.56 kg which at 9 months of age were fed with grower finisher formulation (GF) for 98 days up to an average age of 361 days and compared with commercial feed. Data of BWT (every 2 weeks) and residual feed (daily) were collected.

Flushing and maintenance stage

In a separate experiment, a total of 20 female Katjang-Boer crossbred goats of 1 year of age with an average weight of 24.25 ±1.25 kg were placed into two treatment groups fed with formulated flushing feed (FF) and compared with commercial dam and kid feed kept for 97 days which were fed 2.8 % body weight with a ratio of 60% forage and 40% concentrate. Data of BWT (monthly) and residual feed (daily) were collected. Finally, a total of 20 male Katjang-Boer crossbred goats of 1 year of age with an average weight of 19.05 ± 4.48 kg were placed into two treatment groups fed with formulated maintenance feed (MF) and compared with commercial maintenance feed (CMF) kept for 155 days and fed 2.8% body weight with a ratio of 60% forage and 40% concentrate (Kearl, 1984). Data of weight gain (monthly) and balance feed (daily) were collected (Hifzan *et al*., 2012).

Proximate analysis

Three samples of completed feed of formulated creep feed (CF), starter-grower (SG), grower-finisher (GF), flushing (FF), maintenance (MF), commercial maintenance (CMF) and commercial dam and kid feeds (CCM) along with forages (*Bracharia humidicola)* were taken randomly. Samples were sent for proximate analysis at the Technical Service Centre, MARDI. TDN (Total Digestible Nutrient) and ME (Metabolizable Energy) were calculated based on a regression equation for ruminant described by McDowell *et al*. (1974) as follows:

% Nitrogen free extract (NFE) =
100 - CP - EE - CF - ASH
% Total Digestive Nutrient (TDN) =
92.462 - 3.338 (Crude fibre) - 6.945 (Ether extract) -0.762(NFE) + 1.115(Crude Protein) + 0.031 (Crude Fibre)^2 - 0.133 (Ether Extract)^2 + 0.036 (Crude Fibre) (Nitrogen Free Extract) + 0.207 (Ether Extract) (Nitrogen Free Extract) + 0.100 (Ether Extract) (Crude Protein) - 0.022 (Ether Extract)^2 (Crude Protein)

Metabolizable Energy, ME (MJ/kg) =
0.89 + 0.1646(TDN)

Descriptive and statistical analysis

Weight gain and ADG between treatment groups were analysed with SPSS 10 using independent sample T-test. A descriptive study of metabolised energy (MJ/kg), crude protein supplied (g/day) and percentage dry matter intake (%) supplied through dry matter intake of feed were calculated based on proximate analysis of formulated ration, commercial rations and forage (*Bracharia Humidicola*). Graphs were plotted based on feed intake data and compared between supplies based on Kearl (1984). Feed costs were also calculated based on the cost of raw materials and commercial feed purchase in the time frame of when the experiments were conducted (Hazwan *et al*., 2016).

RESULT AND DISCUSSION

Table 2 shows that Katjang-Boer crossbred achieved a significantly higher BWT of 5.5 kg and ADG of 40.4 g at preweaning stage with CF supplementation than CCM. Post- weaning BWT with SG ration observed a significantly higher BWT of 7.1 kg and ADG of 29.78 g than CCM at 223 days of age. Following that, GF feed had a significantly higher BWT of 12.45 kg and ADG of 56.30 g at 361 days than CCM.

Feeding at maintenance level in male Katjang-Boer crossbred goats (Table 3) observed a significantly higher ADG of 30.65 g in CCM than in formulated MF feed, but at higher cost of feed compared to MF formulation. Feeding at the flushing stage for female Katjang-Boer crossbred goats observed a significantly higher ADG of 18.05 g in formulated FF feed than in CCM feed, with a similar cumulative feed cost of RM 46 for 97 days (Table 4).

Total cumulative feed costs up to 361 days of growth were higher in formulated feed of RM 147.73 compared to commercial feed of RM

128.44 (Table 5). However, feed cost per kg gain obtained in CF (RM 5.68), SG (RM 9.03) and GF (RM 6.57) were lower compared to CCM of RM 6.14, RM 10.27 and RM 12.99 respectively.

Proximate analysis of feed observed higher metabolizable energy and crude protein achieved in all formulated feed (CF, SG, GF, FF and MF) compared to commercial feed (CCM and CMF) (Table 6). Forage sources (*Bracharia humidicola*) were lower than that published by Yusoff *et al.* (1990) (Table 6).

Figure 1 demonstrates a higher growth rate when fed formulated feed (CF, SG and GF) up to 361 days when compared to CCM feed. In Figure 2, it was observed that total energy supplied exceeded requirement at 179 days. However, CCM feed remained lower than requirement up to 361 days. Crude protein supplied exceeded requirement by day 91 however, CCM feed remained lower than requirement up to 361 days (Figure 3). Total dry matter intake both exceeded the requirement with formulated feed observed earlier at day 91 compared to CCM at 152 days of age (Figure 4).

The better growth performance seen in Figure 1 supports the claim by Htoo *et al*. (2015) that kids supported with a good preweaning diet provides a better postweaning performance due to higher weaning weight achieved. Milk replacers allow a continuous production of volatile fatty acid (VFA) which aids in the development of rumen in kids. This is because although the oesophageal grove is closed at a young age, small gaps that remain allow a spill over of the omasum fill (Lane and Jesse, 1997). The mixture of feed consumed with gastrointestinal fluid would allow the liquid to pass these gaps and may lead to earlier rumen development through the development of rumen papillae. This was further supported with findings by Htoo *et al*. (2018) that found higher surface area and greater length of papillae found in treatment group fed creep feed as opposed to kid fed with only dam milk. Further study can be conducted through inspection of the rumen of postweaning Katjang-Boer supplemented diet employed in the current study in order to support this claim. The inclusion of milk replacer in creep feed formulation could have led to an earlier development of rumen function which was observed by an early dry matter intake at 45 days of 1.17% of BWT compared to conventional commercial feed earliest at 59 days at 1.00% BWT (Figure 4). A drop of ADG (Figure 1) was also observed in creep feed formulated kids between 45 and 59 days of 74 g and 64 g before spiking again to 121 gm at 73 days which shows the drop of milk yield in dam after peak at 2 weeks of lactation affecting the growth of preweaning kids. With the support of creep feeding, it allows the preweaning kids to regain a good growth performance (Htoo *et al*., 2015). Thus, creep feed supplementation should be introduced as early as 6 weeks of age or earlier in order to support the nutritional need for growth due to the drop in the quantity of dam milk.

Higher preweaning weight gain stimulates an improved postweaning performance (Goetsch *et al*., 2002) which was also observed in the current study (Figure 1). It was observed that preweaning body weight achieved in the current study was lower at 193 days at 18.92 kg and 19.5 kg at 207 days (Figure 1) with a concentrate to forage ratio of 50:50 supplied with energy density feed of 12.67 ± 0.66 MJ/kg DM in concentrate and 6.43 ± 0.83 MJ/kg DM in the forage (Table 6). Higher energy and protein supplied through creep feeding followed by a growing formulate had improved postweaning performances. This may later lead to earlier puberty and subsequently improving production efficiency. This is because in a study done by Greyling (2000), it was found that animal fed with an energy density of 9.61 MJ/kg DM achieved a puberty weight of 30.6 ± 7.2 kg compared to animals fed with energy density feed of 7.69 MJ/kg DM that achieved lower puberty weight of 27.5 ± 4.3 kg in Boer does. In this current study, with a feeding ratio of 50:50 (concentrate:grass), total energy supplied would be 9.55 MJ/kg DM, close to the reported study by Greyling (2000) which indicates sufficient nutrient supplied. Further study should be done to evaluate reproductive performances of Katjang-Boer using stage feeding formulation employed in the current study to further support the findings in this current study. No reproduction performances were evaluated in this study. However, improvement in BCS is generally regarded as a parameter to improve breeding performance (MacDonald et al., 2002). Therefore, in the current study, ADG is used as a parameter to evaluate the improvement of BCS prior to breeding and the economic implications.

The cost of formulated feed is relatively higher for formulated feed of creep feed (RM 1.67/kg), starter grower feed (RM 1.25/kg) and grower finisher (RM 1.11/kg) compared to commercial feed (RM 1.00 /kg). The total cumulative cost of goats kept for 361 days amounts to RM 147.73 for formulated feed compared to RM 128.44 for commercial feed (Table 5). However, the benefits outweigh the cost through lowered feed cost per kilogram gain obtained in formulated feed compared to commercial feed (Table 5). This was achieved by meeting nutrient requirements of different stages of growth while reducing the cost of feed per kg from creep feed to grower-finisher using least cost formulation module. Though, proximate analysis of ME and CP (Table 6) reduced from creep feed to starter grower feed, but with the increase in DMI (Figure 4), nutrient requirements (Figure 2 and Figure 3) were still met. Cost of formulated flushing feed (RM 1.12/kg) was higher but when fed at a lower amount at 0.428 kg to achieve a similar cumulative cost of feed as commercial feed of RM 46, a significantly higher ADG was observed (Table 4). As for maintenance feed, although a significantly lower ADG was obtained of 42.90 ± 11.98 gm in formulated feed compared to 73.55 ± 19.40 gm in commercial feed, a lower cumulative cost of RM 64.55 compared to RM74.40 (Table 2) was achieved. Maintenance feed was designed only to maintain the BWT of Katjang-Boer crossbred goats at a minimum

Table 1. Feed formulation requirement of targeted and calculated requirement assuming total consumption

Formulation	Diet specifications	Feed unit	Targeted nutrient intake	Calculated nutrient intake
Creep feed	15 kg, 3.3%, DMI, 50 g ADG	ME (MJ/kg) CP (g)	5.43 55	6.34 103.63
	25 kg, 2.9% DMI, 75 g ADG	ME (MJ/kg) CP (g)	6.99 71	6.69 90.08
Grower finisher feed	40 kg, 2.5% DMI, 75 g ADG	ME (MJ/kg) CP (g)	9.08 92	8.92 108.66
Flushing feed	50 kg, 2.5% DMI, 125 g ADG	ME (MJ/kg) CP (g)	11.68 118	10.40 122.11
Maintenance feed	60 kg, 2.1% DMI, 0 g ADG	ME (MJ/kg) CP (g)	94 9.33	128.33 10.37

Table 2. Mean ± SD of BWT and ADG of Katjang x Boer goats on creep feed (CF) (101 days), starter grower (SG) (223 days) and grower finisher (GF) (361 days) against commercial feed (CCM).

Parameters	N[1]	Age[2] (days)	Creep feed[3]	Commercial feed
Weaning weight, BWT (kg)	12	101	12.83± 3.61*	7.33 ± 1.13
Average daily gain, ADG (g)			91.8 ± 32.7*	51.4 ± 11.96
			Starter grower feed	Commercial feed
Bodyweight, BWT (kg)	24	223	22.20 ± 2.78*	15.10 ± 2.61
Average daily gain, ADG (g)			86.73 ± 28.20*	56.95 ± 18.01
			Grower finisher feed	Commercial feed
Bodyweight, BWT (kg)	24	361	31.5 ± 4.67*	18.96 ± 3.49
Average daily gain, ADG (g)			75.26 ±15.55*	44.05 ±38.51

Values with asterisk within columns are significantly different at $p < 0.05$

[1]N refers to the sample size

Table 3. Mean ± SD (N=10) of male Katjang x Boer goats of BWT, ADG, total feed cost and cost per kg feed of maintenance feed (MF) compared to commercial feed (CCM).

Parameters	Formulated maintenance feed	Commercial maintenance feed
Average weight (155 day BWT, (kg)	25.7 ± 3.78	30.95 ± 4.30*
Average Daily Gain, ADG (g)	42.90 ± 11.18	73.55 ± 19.40*
Total feed cost per animal for 155 days (RM)	63.55	74.40
Cost of feed (RM/kg)	0.86	1.00

Values with asterisk within columns are significantly different at $p < 0.05$

Table 4. Mean ± SD (N=10) of female Katjang x Boer Goats of BWT, ADG, average feed consumed per day, total feed cost and cost per kg feed of flushing feed (FF) compared to commercial feed (CCM)

	Formulated flushing feed	Commercial dam and kid feed
Average weight (97 days) BWT (kg)	30.75 ± 1.46	29.60 ± 1.82
Average Daily Gain, (ADG) (gm)	67.01 ± 16.11*	48.97 ± 16.86
Average Feed consumed per animal per day (kg)	0.428	0.475
Total feed cost per animal for 97 days (RM)	46.49	46.08
Cost of feed (RM/kg)	1.12	1.00

Values with asterisk within columns are significantly different at $p < 0.05$

Table 5. Summary of feed consumed and cost of male Katjang x Boer goats kept for 361 days on formulated feed compared with commercial feed under intensive

Age (days)	Type of feed	Cost per kg concentrate feed (RM)		Formulated feed			Commercial feed		
		Formulated	Commercial	Cumulative feed consumed (kg)	Cumulative cost feed/ animal (RM)	Feed cost per kg body weight gain (RM/kg)	Cumulative feed consumed (kg)	Cumulative cost feed/ animal (RM)	Feed cost per kg body weight gain (RM/kg)
0-101	Creep	1.67	1.00	17.50	29.23	5.68	13.16	13.16	6.14
102-164 (Adaptation)	Creep/ starter grower	1.67/1.25	1.00	27.80	40.58		23.44	23.44	
165- 235	Starter grower	1.25	1.00	75.96	94.95	9.03	64.45	64.45	10.27
236-262 (Adaptation)	Starter grower-Grower finisher	1.25/1.11	1.00	84.12	99.26		72.44	72.44	
263- 361	Grower finisher	1.11	1.00	133.09	147.73	6.57	128.44	128.44	12.99

cost especially while goats are kept for specific periods of culling such as for religious festivals or practices (Hifzan *et al*., 2018). The reduction of cost of feed of RM 10 for a period of 5 months per animal would help reduce the overall farm operative cost.

Accurate estimation of goat requirements allows a better prediction of growth through nutrients supplied (Kearl *et al*., 1984; Sahlu *et al*., 2004). Recent studies showed data collected through mathematical modules by AFRC produce the most accurate DMI prediction and CSIRO the most accurate ADG prediction when compared between requirements in AFRC, CSIRO, SRNS and NRC (Auxiliadora *et al*., 2011). Another study conducted on the use of NRC (2007) and INRA (2007) in calculating nutrient requirements showed minimal differences (Martínez Marín *et al*., 2010). However, these requirements were designed to meet the need for temperate conditions. Kearl (1984) produced a table of nutrient requirements in tropical goats for maintenance, growth, early gestation, and lactation which were used in the current study. This table of requirement was constructed through analysis of various nutrient requirement studies of tropical animals. Based on DMI (Figure 3), given protein supply exceeded requirement by day 73. However, ME only exceeded requirement at day 179 which shows energy remains the limiting nutrient component for optimum production. Requirement studies have found that metabolizable energy for maintenance (MEm) for small ruminants in warm tropical climate was found to be higher compared to temperate climate (Salah *et al*., 2014). Sahlu *et al.* (2004) also agreed that energy requirements for gain in tropical climate were higher in particular for indigenous breeds which could be due to energy metabolism related to

Table 6. Mean and standard deviation (N=3) of proximate analysis of formulated feed, commercial feed and forages

Component	Formulated creep feed (CF)	Formulated starter grower feed (SG)	Formulated grower finisher feed (GF)	Formulated maintenance feed (MF)	Formulated flushing feed (FF)	Dam and kid commercial feed (CCM)	Maintenance commercial feed (CMF)	Forage (*Bracharia humidicola*)
Gross Energy (cal/gm)	3871.22 ± 80.40	3789.23 ±122.89	3970.12 ±95.65	3816.71 ±265.37	3856.00 ±128.61	3731.67 ± 136.90	3718.83 ±143.15	3841.64 ± 94.30
Total Digestible Nutrient (%)	85.24 ± 2.18	82.35 ± 3.98	79.14 ±5.55	69.37 ±10.56	79.37 ±4.79	64.83 ±7.50	64.24 ±4.10	44.47 ± 5.03
Metabolisable Energy (MJ/kg)	13.14 ± 0.36	12.67 ± 0.66	12.14 ±0.91	10.53 ±1.74	12.17 ±0.79	9.78 ±1.24	9.68 ±0.63	6.43 ± 0.83
Crude Protein (%)	20.82 ±3.41	18.14 ± 1.70	17.69 ±1.27	15.37 ±2.13	16.72 ±1.46	13.92 ±2.21	12.40 ±0.73	5.84 ± 0.44
Ether Extract (%)	3.64 ±0.49	4.16 ± 0.74	4.59 ±0.58	4.35 ±3.59	4.92 ±1.65	3.13 ±2.26	2.39 ±1.43	1.52 ± 0.69
Crude Fibre (%)	5.33 ±0.31	8.53 ±1.51	12.16 ±4.46	15.24 ±2.14	10.73 ±2.76	21.20 ±2.76	18.84 ±1.12	39.10 ±1.44
Dry matter (%)	87.17 ±0.84	87.45 ±0.45	87.90 ±0.89	88.25 ±1.57	87.66 ±1.30	88.42 ±0.53	87.61 ±1.43	19.80 ±0.90
Ash (%)	5.26 ±0.51	5.90 ±0.04	5.64 ±0.70	6.84 ±0.20	5.52 ±0.46	7.13 ±0.90	6.85 ±0.21	4.74 ±0.40
Neutral Detergent Fibre (%)	37.84 ±9.12	48.51 ±6.57	52.72 ±2.75	55.15 ±3.21	53.05 ±8.10	59.86 ±5.02	60.44 ±2.56	83.97 ± 4.00
Acid Detergent Fibre (%)	9.47 ±1.78	18.01 ±1.78	21.45 ±1.31	29.14 ±1.29	22.37 ±1.07	32.71 ±2.98	31.71 ±4.90	41.42 ±0.96
Acid Detergent Lignin (%)	2.39 ±1.08	5.05 ± 0.23	5.87 ±1.32	8.00 ±0.40	5.49 ±1.21	8.76 ±0.75	8.09 ±1.58	6.19 ±0.55
Phosphorus (%)	0.50 ±0.03	0.46 ± 0.07	0.49 ±0.11	0.69 ±0.09	0.44 ±0.02	0.40 ±0.50	0.84 ±0.24	0.27 ±0.07
Calcium (%)	1.05 ±0.22	1.10 ± 0.06	1.14 ±0.30	1.19 ±0.16	1.04 ±0.10	1.15 ±0.05	1.13 ±0.41	0.1 ±0.05

tropical climate and local indigenous breeds. Lower maintenance requirements would lead to lower residual feed and are likely to have higher efficiency in digestion and metabolization of nutrients (Vandehaar *et al*., 2016). However, in the current study, nutrient needs of the different production stages of Katjang x Boer goats were met through different formulations (Kearl,1984). Further research in nutrient requirement for local goat breeds in a humid tropical climate should be conducted to improve precision feeding regimes in Malaysia for optimum growth. Limitation of the current experimentation is that the same animal could not be used for all the different production stages due to time constraints as all experimentations were ran simultaneously. However, animals chosen for the experimentations in the current study were randomized with similar genetic make ups, starting weight and environmental conditions in order to minimize errors. Future experimentation could be focused on the use of the same animals

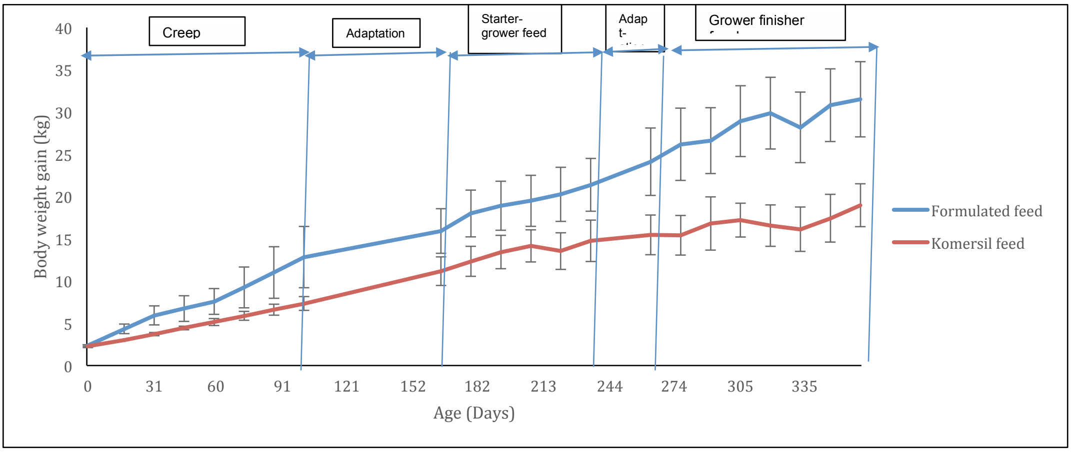

Figure 1: Growth performance of Katjang x Boer goats kept for 361 days of age on formulated feed compared to conventional commercial feed

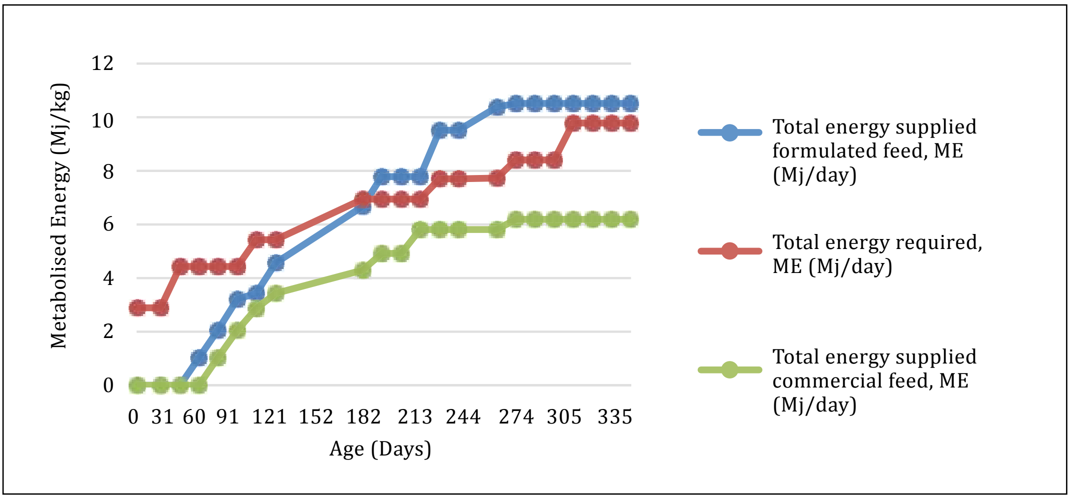

Figure 2: Total metabolised energy (supplied and required) of male Katjang x Boer goats on formulated feed and commercial feed

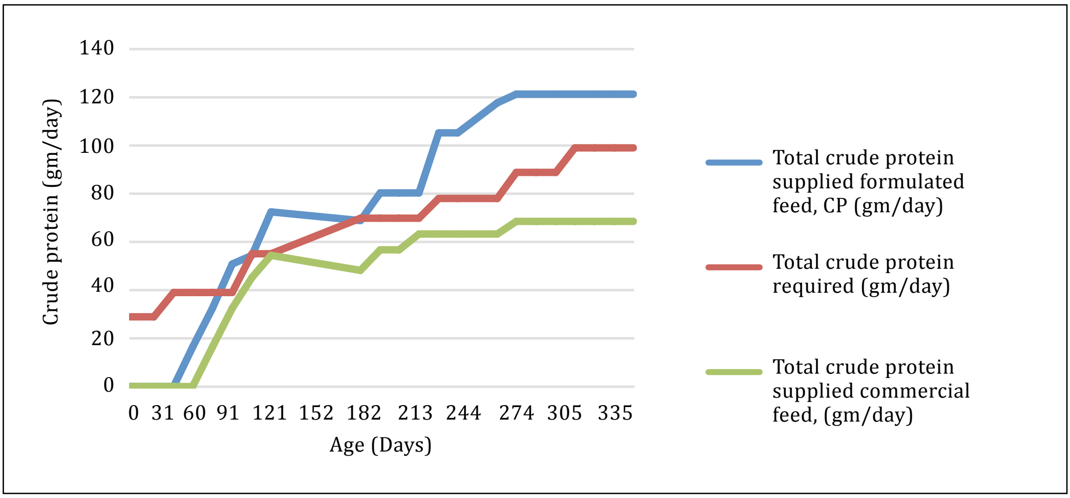

Figure 3: Total crude protein (supplied and required) of male Katjang x Boer goats on formulated feed and commercial feed

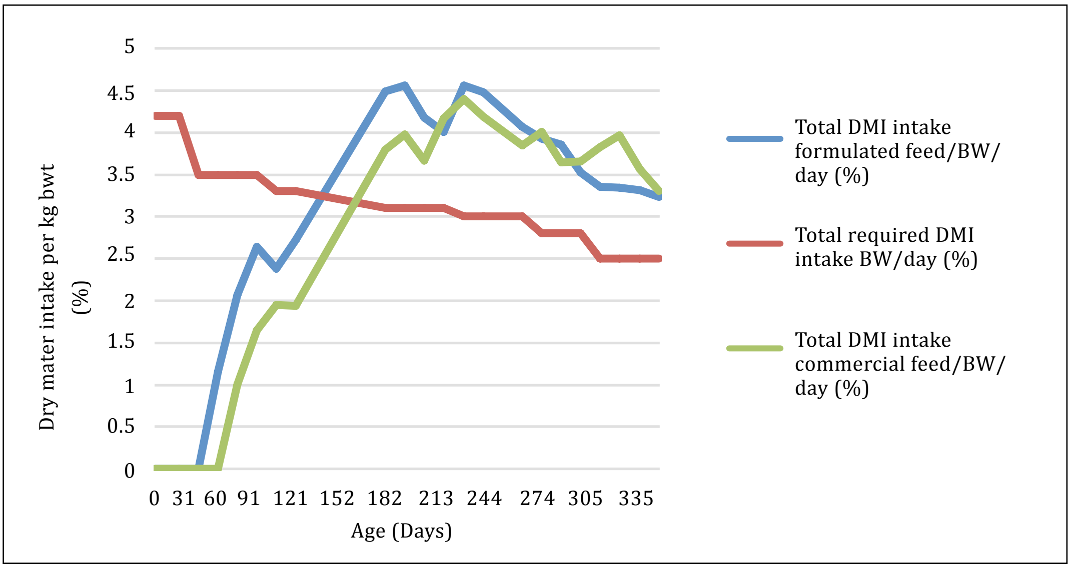

Figure 4: Total dry matter intake (supplied and required) of male Katjang x Boer goats on formulated feed and commercial feed

for all production stages in the context of studying the benefits of stage feeding.

CONCLUSION

This study shows that stage feeding of the different production stages was observed to be more economically viable by fulfilling the nutritional needs of Katjang-Boer crossbred through reduced cost per kilogram weight gain and higher ADG achieved. Overall, better performance was observed in Katjang x Boer goats fed using stage feeding strategies applied in this study.

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