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Herbal Mineral Block Supplementation Containing Turmeric Flour, Black Soldier Fly, and Micro Minerals on Performance and Blood Profile of Dorper Crossbred Sheep

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ABSTRACT

This study aimed to determine the effect of herbal mineral block (HMB) supplementation containing turmeric flour, black soldier fly (BSF), and micro minerals on the performance and blood profile of Dorper crossbred sheep. Ten growing sheep and ten lactating sheep were divided into two treatment groups (P0: complete feed without HMB supplementation and P1: complete feed with HMB supplementation). The research design used was a factorial completely randomized design (2 × 2) with 5 replications. Factor physiological status of growing and lactating sheep and factor supplementation with and without HMB. The data were analyzed using ANOVA and Duncan's test. The results showed no interaction between physiological status and HMB supplementation on sheep performance (nutrient intake, initial and final body weight, daily body weight gain, and feed efficiency) and blood profile (hematology, metabolites, and minerals). The physiological status had a very significant effect ($p<0.01$) on nutrient intake, initial and final body weight, daily body weight gain, feed efficiency, and significantly ($p<0.05$) on serum phosphorus. Supplementation of HMB significantly ($p<0.05$) increased serum calcium which was crucial for bone an teeth development in growing sheep and milk production in lactating sheep. Serum phosphorus was higher in growing sheep, supporting their bone growth and energy metabolis compared to lactating sheep as it was diverted to the mammary gland.

Keywords: *Herbal mineral block, Performance, Blood profile, Dorper crossbred sheep*

Introduction

Sheep is a strategic commodity that is an integral part of other farming businesses and a contributor to national meat procurement. Dorper sheep is a superior breed of sheep in Indonesia that has promising economic and production potential through cross breeding with local sheep. Dorper sheep can reach a weight of 36 kg at the age of 3.5 – 4 mon (Sholikhah *et al*., 2022). It has the ability to grow fast, high productivity with ADG of 145.79 g/d, birth weight of 2.70 kg, lambing interval of 214.67 d, and mortality of 7.45% (Athifa *et al*., 2022). Dorper sheep is a cross of the Dorset Horn (south-west England) and the Blackhead Persian (Persia). Dorper sheep exhibit outstanding adaptability, physical toughness, rapid growth, reasonable reproductive rate, and lamb-rearing ability (Deribe *et al*., 2023).

Minerals have essential roles in livestock, such as growth, health, immunity, production, and reproductive purposes (Yanuartono *et al*., 2016). The minerals calcium (Ca) and phosphorus (P) are essential for sheep for bone and tooth development, milk production and play a role in the phosphorylation and oxidation of several important enzymes in the body (Bhalakiya *et al*., 2019). Deficiencies in calcium, phosphorus and micro minerals such as zinc (Zn), selenium (Se) and chromium (Cr) can significantly impair growth performance and immune function in sheep (Jin *et al*., 2023). Herbal mineral block (HMB) is a supplementation technology in the form of blocks containing herbs and enriched with minerals to improve immunity and productivity of sheep printed solid in block form (Singh *et al*., 2015) and its administration by hanging in the cage parallel to the head of the livestock so that it can be licked.

Supplementation in the form of block feed has been done, like urea molasses multi-nutrient block (UMMB), which has a positive effect on increasing body weight and blood biochemistry in sheep (Muralidharan *et al*., 2015). The feed block contained herbal ingredients such as turmeric flour

(*Curcuma domestica*) in this study, which can boost the immune system and increase appetite to make healthy livestock. The content in turmeric contains curcuminoids, essential oils, vitamin C, vitamin E and the mineral Selenium (Prasetiadi *et al*., 2017), which functions as an antioxidant, pathogenic antimicrobial, anti-inflammatory, and anti-glycemic properties. This content can improve sheep performance. Other ingredients added to HMB such as quicklime as a cation binder, molasses and pollard/bran as energy sources, black soldier fly (BSF) larval flour as a source of protein, correcting protein/nitrogen deficiency and as an antimicrobial growth promoter and immunomodulator (Fitriana *et al*., 2022). Thus it aimed to determine the effect of HMB on the performance and blood profile of Dorper x Hairsheep crossbred sheep with the different physiological status.

Materials and Methods

Location and duration

The research was conducted from November 2023 to January 2024. Maintenance was carried out at Sumatra Martabe Farm, Deli Serdang Regency, North Sumatra. Proximate analysis was conducted at the Biotech Center Laboratory of IPB University and PT Saraswati Indo Genetech Laboratory. Blood profile analysis was carried out at the Animal Nutrition Laboratory Meat and Work and the Dairy Animal and Nutrition Laboratory, Faculty of Animal Science, IPB University.

Ethics approval

This study was conducted in accordance with ethical guidelines and received approval from the Animal Care and Use Committee (ACUC) at IPB University, with ethical clearance number 122-2022 IPB.

Research Procedure

This study used Doper x Hairsheep crossbred sheep with different physiological status (growth and lactation). Growing sheep amounted to 10 heads with an average body weight of 17.52 ± 1.67 kg 3 mon old. Lactating sheep amounted to 10 heads with an average body weight of 36.33 ± 3.17 kg 1 year old and the first lactation period. Treatments were divided into two groups (P0: complete feed without HMB supplementation and P1: complete feed with HMB supplementation). This study was carried out for eight weeks, with initial, final, and weighing every other week and adaptation was carried out for two weeks. Sheep feed in complete feed from Sumatera Martabe Farm was given as much as 4% of body weight. Feed was given three times a day, in the morning at 08.00 am, in the afternoon at 01.00 pm and in the evening at 05.00 pm, while drinking water was given ad libitum. Give HMB by hanging using a rope parallel to the sheep's head. The final weight of HMB fed to sheep is ± 2 kg. Feed intake was measured after 24 h, and HMB weighing was performed every 7 d until the end of the study. The formulation of HMB can be seen in Table 1 and nutrient content in Table 2. Blood sampling was done at the end of the study. The experimental design used a factorial completely randomized design (2x2) with 5 replications. Factor physiological status of growing and lactating sheep. Factor supplementation with and without HMB.

Table 1. HMB formulation for Dorper crossbred shepp

Material	Composition (%)
Molasses	34
Pollard	30
BSF larvae defatted flour	10
Turmeric flour	5
$CaCO_3$	14
Yod-free salt	5
Premix*	2
Total	100

**Premix composed of Mg 17142.86 ppm, Fe 12.50 Zn 9.74 ppm, Mn 5.47 ppm, Cu 2.00 ppm, Cr 0.11, Se 0.05, I 0.03, Co 0.02 ppm.*

Table 2. Nutrient content of complete feed and HMB for Dorper crossbred shepp (% DM)

Nutrien Content	Composition (%)	
	Complete Feed[1]	HMB[2]
Dry matter	69.09	82.16
Crude protein	11.23	11.86
Crude fiber	11.01	4.71
Ether extract	1.80	1.30
Ash	4.35	22.14
Nitrogen-free extract (NFE)[a]	71.62	59.99
Total Digestible Nutrient (TDN)[b]	80.31	66.13
Calcium (Ca)	0.89	6.06
Phosphorus (P)	0.45	0.24

[1)]Analysis result of IPB Biotech Center Lab (2023) and Dairy Animal and Nutrition Lab (2023). [2)] Analysis results of IPB Biotech Center Lab (2023) and PT Saraswati Indo Genetech Lab (2023). [a]NFE=100-(% ash+ %CF + %CP+ %EE). [b]TDN is calculated based on Sutardi (2001); TDN (%) = 2.79 + 1.17 CP + 1.74 EE - 0.295 CF + 0.810 NFE.

Measured variables and data analysis

The variables observed in this study included sheep performance, which consisted of nutrient intake, HMB consumption, intial body weight, final body weight, average daily weight gain, and feed efficiency. Blood profile analysis included hematological profile, blood metabolites, and serum minerals. Data were analyzed using analysis of variance (ANOVA). If there were significant differences, it would be followed by Duncan's Further Test using SPSS 25.0 statistical software (IBM Corp., Armonk, NY, USA).

Results and Discussion

Nutrient Intake of Dorper crossbred sheep

The nutrient intake of the sheep can be seen in Table 3. It showed no interaction between physiological status and HMB treatment on the nutrient intake of sheep. The treatment of HMB had no significant effect on the nutrient intake of sheep. Feeding herbal mineral blocks containing herbal ingredients such as turmeric or ginger does not interfere with the palatability of the sheep (Nurmi & Harahap, 2019). The physiological status had a very significant effect ($p<0.01$) on the nutrient intake of sheep.

Table 3. Nutrient intake of Dorper crossbred sheep

Variables	Physiological status	HMB treatment		Mean
		P0	P1	
DM (g/d)	Growth	1032.24±71.27	998.44±50.29	1015.34±60.82^{a}
	Lactation	1699.77±225.40	1657.77±125.78	1678.77±173.50^{b}
	Mean	1366.01±385.51	1328.10±359.04	
CP (g/d)	Growth	115.92± 8.00	112.24±5.58	114.08±6.79^{a}
	Lactation	190.88±25.31	186.42±14.16	188.65±19.48^{b}
	Mean	153.40 ± 43.29	149.33±40.39	
CF (g/d)	Growth	113.65±7.85	108.74±6.19	111.20±7.15^{a}
	Lactation	187.14±24.82	179.96±13.57	183.55±19.23^{b}
	Mean	150.40±42.44	144.35±38.83	
EE (g/d)	Growth	18,53±1,28	17,83±0,95	18.18±1.13^{a}
	Lactation	30,51±4,05	29,56±2,23	30.03±3.12^{b}
	Mean	24.52±6.92	23.69±6.39	
NFE (g/d)	Growth	739.29±51.04	712.89±37.21	726.09±44.35^{a}
	Lactation	1217.38±161.43	1182.58±89.45	1199.98±124.40^{b}
	Mean	978.33±276.10	947.73±255.83	
TDN (g/d)	Growth	829.02±57.24	799.20±41.85	814.11±49.81^{a}
	Lactation	1365.13±181.03	1325.64±100.25	1345.39±139.52^{b}
	Mean	1097.07±309.61	1062.424±286.76	
Ca (g/d)	Growth	9.19±0.63	9.81±0.33	9.50±0.58^{a}
	Lactation	15.13±2.01	16.75±1.85	15.94±2.01^{b}
	Mean	12.16±3.43	13.28±3.87	
P (g/d)	Growth	4.65±0.32	4.45±0.25	4.55±0.29^{a}
	Lactation	7.65±1.01	7.37±0.56	7.51±0.78^{b}
	Mean	6.15±1.73	5.91±1.59	

[a,b]*Means in the same column and row with different letters show very significant differences* ($p<0.01$). *DM : Dry matter, CP: Crude protein, CF=:Crude fiber, EE: Ether extract, NFE: Nitrogen-free extract, TDN: Total digestible nutrient, P0: Complete feed without HMB supplementation, P1: Complete feed with HMB supplementation*, *Ca: Calcium, P: Phosphorus*.

The average dry matter intake in lactating sheep was 39.50% higher than that of growing sheep. The consumption requirements of dry matter for growing sheep with body weight of 10 – 20 kg are 498.96 – 997.92 g/d and the first 4-6 wk of lactating sheep 1587.60 – 1678.32 g/d (NRC, 2007). The results of dry matter intake of Dorper lambs are around 1031 – 1502 g/d (Rangkuti *et al*., 2024) in lactating sheep 931.24 – 1225.3 g/d (Nurlatifah *et al*., 2022).

The consumption requirements crude protein for growing sheep with body weight of 10-20 kg are 127 – 167 g/d and the first 4-6 weeks of lactating sheep 175 – 184 g/d (NRC, 2007). The results of crude protein intake of growth sheep are 110.16 ± 8.08 – 152.84 ± 12.13 g/d (Suharti *et al*., 2019), and in lactation sheep are 149.27 ± 26.88 - 184.05 ± 24.17 g/d (Nurlatifah *et al*., 2022). The results of consumption of crude fiber, ether extract, and nitrogen-free extract intake in growth sheep are 119.86 ± 17.94 g/d, 22.32 ± 3.30 g/d and 306.95 ± 45.33 g/d, respectively (Budi *et al*., 2021), and in lactation sheep 154.31 ± 13.61 g/d, 62.64 ± 4.77 g/d and 357.69 ± 30.11 g/d, respectively (Khotijah *et al*., 2020).

The consumption requirements total digestible nutrient (TDN) for growing sheep with body weight of 10 – 20 kg are 408.24 – 815.48 g/d and lactating sheep 4 – 6 wk first 952.56 – 997.92 g/d (NRC, 2007). The macro mineral requirements needed by growing sheep with body weights reaching 20 kg are calcium (Ca) 3.4 g/d and phosphorus (P) 3.0 g/d. The requirement for lactating sheep is calcium 6.1 g/d and phosphorus 5.4 g/d (McDonald *et al*., 2012).

The average consumption of HMB in Dorper crossbred sheep for 8 wk can be seen in Table 4. Dry matter consumption of HMB in lactating sheep has a high level of consumption due to the influence of the level of mineral requirements of several sheep in producing milk for the nutritional needs of lambs (Galvani *et al*., 2014). The level of HMB consumption is also influenced by the mineral status of the sheep which is sufficient. Unlike concentrate feed, HMB is consumed by licking by livestock. If the mineral needs of the sheep are met, the sheep will stop licking the HMB (Arrizqi, 2020). Consumption of feed in the form of blocks is influenced by the taste, aroma, hardness, physical form, physiological condition and adequacy of the nutritional status of livestock (Mohd Nor *et al*., 2020).

Table 4. HMB consumption of growing and lactating Dorper crossbred sheep for 8 weeks

Variables	Growth sheep	Lactation sheep
Dry matter (g/d)	18,84±12,14	40,60±25,20
Crude protein (g/d)	2,23±1,44	4,81±2,99
Crude fiber (g/d)	0,89±0,57	1,91±1,19
Ether extract (g/d)	0,24±0,16	0,53±0,33
Nitrogen-free extract (g/d)	11,30±7,28	24,35±15,12
Total digestible nutrient (g/d)	12,46±8,03	26,85±16,67
Cacium (g/d)	1,09±0,71	2,36±1,46
Phosphorus (g/d)	0,04±0,03	0,09±0,06

Performance of Dorper crossbred sheep

The initial body weight, final body weight, average daily weight gain and feed efficiency of sheep can be seen in Table 5. It shows no interaction between sheep physiological status and HMB treatment on initial body weight, final body weight, average daily weight gain and feed efficiency. The treatment of HMB had no significant effect on initial body weight, final body weight, average daily weight gain and feed efficiency. The physiological status of sheep had a very significant effect (p<0.01) on initial body weight, final body weight, average daily weight gain and feed efficiency.

Table 5. Average daily weight gain and feed efficiency of Dorper crossbred sheep

Variables	Physiological status	HMB treatment		Mean
		P0	P1	
Intial Body Weight (Kg)	Growth	18.12±1.37	16.93±1.84	17.52±1.67[a]
	Lactation	37.20±3.40	35.46±3.03	36.33±3.17[b]
	Mean	27.64±10.37	26.18±10.06	
Final Body Weight (Kg)	Growth	32.52±1.06	31.62±1.34	32.07±1.24[a]
	Lactation	40.54± 6.01	39.64±1.82	40.09±4.22[b]
	Mean	36.53 ±5.87	35.63±4.49	
ADG (g/head/ day)	Growth	225.63±19.03	230.00±11.87	227.81±15.13[b]
	Lactation	52.19±46.44	65.31±57.57	58.75±49.79[a]
	Mean	138.91±97.34	147.66±95.23	
Feed efficiency (%)	Growth	22.01±3.13	23.58±2.27	22.79±2.71[b]
	Lactation	2.81±2.62	4.02±3.51	3.42±2.99[a]
	Mean	12.41±10.48	13.80±10.68	

[a,b]*Means in the same column and row with different letters show very significant differences (*p<*0.01). ADG: Average daily weight gain, P0: Complete feed without HMB supplementation, P1: Complete feed with HMB supplementation*.

The average daily weight gain of growing sheep was 74.21% higher than lactating sheep. Average body weight gain of weaned Dorper lambs are 195.66 – 261.99 g/head/d (Rangkuti *et al*., 2024). The average daily body weight gain of Dorper sheep aged 110 – 120 d have ranges from 240-280 g/head/d (Gavojdian *et al*., 2015). Decrease in daily weight of lactating sheep by 63.10 g/head/d to a daily weight gain of 45.60 g/head/d during the lactation period (Benchohra *et al*., 2015). Research by Idris *et al*. (2010) that the average increase in daily body weight gain of lactation sheep from the first week to the eighth week is 21.40-37.50 g/head/d.

Feed efficiency in the growing phase of sheep is 85% higher than in the lactation phase, following the higher growth rate in the growing phase. Growth Sheep convert most of their feed intake into body mass because their metabolic focus is on growth and development, which requires efficient use of nutrients to build muscle, bone and other tissues (Deribe *et al*., 2023). In contrast, during lactation, most of the nutrients consumed are diverted to milk production and have increased energy requirements to support milk synthesis (Yulistiani *et al*., 2019). Feed efficiency results that the research dorper sheep reached 18.35% (Saeed *et al*., 2018). The feed efficiency of Dorper x Brazilian Somali sheep at weaning has been observed to reach 20% (Souza *et al*., 2013). The results of feed efficiency of lactating sheep were in line with Mathius *et al*. (2001) that the ratio utilization efficiency of ewe after giving birth reached 3.54% – 5.27% during the 8 wk lactation period.

Hematological profile of Dorper crossbred sheep

The statistical analysis results of the hematological profile are in Table 6. It shows no interaction between the physiological status of sheep and HMB treatment on sheep's erythrocyte, hemoglobin, hematocrit and leukocyte levels. The physiological status of sheep and HMB treatment had no significant effect on the hematological profile of sheep.

Table 6. Hematological profile of Dorper crossbred sheep

Variables	Physiological status	HMB treatment		Mean	Normal
		P0	P1		
Erythrocyte ($10^6/mm^3$)	Growth	10.79±1.02	11.87±1.57	11.33±1.38	9-15*
	Lactation	11.06±0.95	11.66±0.56	11.36±0.80	
	Mean	10.92±0.94	11.77±1.12		
Hemoglobin (g%)	Growth	11.72±0.59	11.20±0.92	11.46±0.78	9-15*
	Lactation	11.56±0.90	11.52±0.90	11.54±0.85	
	Mean	11.64±0.72	11.36±0.87		
Hematocrit (%)	Growth	34.00±4.74	30.40±4.67	32.20±4.83	22-38*
	Lactation	33.40±2.97	29.40±5.08	31.40±4.45	
	Mean	33.70±3.74	29.90±4.63		
Leukocyte ($10^3/mm^3$)	Growth	7.26±1.20	7.63±2.06	7.45±1.60	4-12*
	Lactation	7.31±1.42	7.86±1.25	7.59±1.30	
	Mean	7.29±1.24	7.75±1.61		

**Sarmin et al. (2022)*
P0: Complete feed without HMB supplementation, P1: Complete feed with HMB supplementation.

The average erythrocyte value of the growing phase and lactation phase of sheep as a whole is in the normal range of 9-15 $10^6/mm^3$ (Sarmin *et al*., 2022). Ferrum (Fe), cobalt (Co), and copper (Cu) are important microminerals in erythrocyte production (Astuti *et al*., 2022). These minerals are premixed in herbal mineral blocks according to the levels of livestock needs. The herbal mineral block maintained erythrocyte counts at normal values, meaning the supplementation had no adverse effects.

Average hemoglobin values are normal (9 – 15 g/dL (Sarmin *et al*., 2022). Normal hemoglobin levels align with the consumption of crude protein following the standard needs of livestock and adequate microminerals. Minerals Fe and Cu have an important role in the formation of hemoglobin. Cu functions as a biocatalyst for Fe in the process of hemoglobin synthesis and helps the maturation of erythrocytes (*erythropoiesis*) (Atik *et al*., 2020).

Hematocrit levels were in the normal range of 27% – 45% (Sarmin *et al*., 2022). Some studies state that hematocrit values tend to decrease during the lactation phase. Blood volume increases during pregnancy and lactation, this can cause a decrease in hematocrit values due to *haemodilution*, which is a normal physiological response (Habibu *et al*., 2014).

Leukocyte levels were within the normal range of 4 – 12 $10^3/mm^3$ (Sarmin *et al*., 2022). An increase in leukocytes in the blood indicates the ability of the body's defence system against foreign bodies or infections and improved sheep health (Pizetti *et al*., 2021). Crude protein content in feed will affect leukocyte and erythrocyte levels. This is in line with adequate crude protein consumption following the recommended standards.

Leukocyte differentiation is one of the constituent components of white blood cells that play an essential role in the body's defence system. The results of the statistical analysis are in Table 7. It shows no interaction between physiological status and HMB treatment on sheep's lymphocyte, neutrophil, eosinophil, monocyte and basophil levels. Physiological status and HMB treatment had no significant effect on leukocyte differentiation status.

Table 7. Leukocyte differentiation of Dorper crossbred sheep

Variables	Physiological status	HMB treatment		Mean	Normal
		P0	P1		
Limphocyte (%)	Growth	55.93±0.57	56.10±0.84	56.01±0.68	40-75*
	Lactation	56.05±1.01	56.22±2.43	56.14±1.76	
	Mean	55.99±0.77	56.16±1.72		
Neutrophil (%)	Growth	32.77±0.77	31.85±0.97	32.31±0.96	10-50*
	Lactation	31.94±0.50	31.45±1.39	31.70±1.02	
	Mean	32.35±0.75	31.65±1.15		
Eosinophil (%)	Growth	6.49±0.71	6.77±0.85	6.63±0.75	0-10*
	Lactation	7.04±0.75	7.30±1.59	7.17±1.18	
	Mean	6.77±0.74	7.03±1.24		
Monocyte (%)	Growth	3.53±0.82	3.79±0.70	3.66±0.73	0-6*
	Lactation	3.19±0.72	3.33±1.37	3.26±1.03	
	Mean	3.36±0.75	3.56±1.05		
Basophil (%)	Growth	1.29±0.48	1.50±0.34	1.39±0.41	0-3*
	Lactation	1.79±0.78	1.70±0.51	1.74±0.62	
	Mean	1.54±0.66	1.60±0.42		

**Sarmin et al. (2022)*
P0: Complete feed without HMB supplementation, P1: Complete feed with HMB supplementation.

Lymphocyte percentage is within the normal range (40% – 75%) (Sarmin *et al*., 2022). Lymphocytes are related to the function of lymphocyte cells in the immune response and produce antibodies. Factors affecting lymphocytes are cellular immunity, feed protein content, and environmental factors (Acharya *et al*., 2015). The neutrophil percentage is in the normal range of 10-50% (Sarmin *et al*., 2022). It shows that pathogenic bacteria do not infect sheep. Neutrophils play an important role in phagocytosis and killing microorganisms harmful to the livestock body (Sarmin *et al*., 2020). Eosinophils percentage is in the normal range (0% – 8%) (Sarmin *et al*., 2022). The number of eosinophils produced by an animal's body can determine the animal's level of resistance to disease infection (Atik *et al*., 2020).

Monocyte percentage is in the normal range (0% – 6%) (Sarmin *et al*., 2022). This means that no microorganisms enter the body. Monocytes as macrophages play an important role in immune recreation and phagocytosis of bacteria and microorganisms. Basophils percentage is in the normal range (0% – 3%) (Sarmin *et al*., 2022). It does not interfere with blood circulation, thus preventing blood clots (Astuti *et al*., 2022). Basophils are associated with viral infections, ectoparasites, allergies, and inflammation focused on blood clotting (Santika *et al*., 2022).

Blood metabolites of Dorper crossbred sheep

The results of the statistical analysis of blood metabolites are in Table 8. It showed no interaction between sheep physiological status and HMB treatment on total protein and albumin. This means that HMB treatment affects total protein and albumin levels similarly, regardless of whether the sheep are growing or lactating. It was reported that the physiological condition of sheep had no significant effect on albumin and total protein levels (Sarmin *et al*., 2022).

Table 8. Blood metabolites of Dorper crossbred sheep

Variables	Physiological status	HMB treatment		Mean	Normal
		P0	P1		
Total Protein (g/dl)	Growth	6.74±0.22	7.50±1.53	7.12±1.10	6.00-7.90*
	Lactation	6.95±0.18	7.07±0.60	7.01±0.42	
	Mean	6.84±0.22	7.28±1.12		
Albumin (g/dl)	Growth	3.69±0.06	3.92±0.27	3.81±0.22	2.60-4.20*
	Lactation	3.65±0.13	3.74±0.21	3.70±0.17	
	Mean	3.67±0.10	3.83±0.25		

**Barbosa et al. (2023)*
P0: Complete feed without HMB supplementation, P1: Complete feed with HMB supplementation.

Feed crude protein consumption and metabolic processes' effectiveness influence total blood plasma protein. Total protein levels were within the normal range (6.00 – 7.90 g/dL) (Barbosa *et al*., 2023). Total protein in blood plasma is influenced by the protein content of the feed and the level of crude protein consumption of the livestock. Total blood protein regulates blood osmotic pressure to determine cell membrane permeability (Permana *et al*., 2020).

Albumin levels were within the normal range (2.60 – 4.20 g/dL) (Barbosa *et al*., 2023). Albumin is the largest protein in the blood. The amount of albumin in animal blood plasma protein is about 35% – 50%. Albumin also transports minerals such as Zn, which activate enzymes that form livestock products and regenerate cells (Irfan *et al*., 2014).

Serum minerals of Dorper crossbred sheep

The results of the statistical analysis of blood minerals are in Table 9. It showed no interaction between physiological status and HMB treatment on serum Ca and P. Supplementation of HMB had a significant effect ($p<0.05$) on serum Ca. This is due to the effect of calcium mineral content in the herbal mineral block being higher than that of other minerals, so there is an increase in serum Ca in livestock given the herbal mineral block.

Table 9. Serum Ca and P of Dorper crossbred sheep

Variables	Physiological status	HMB treatment		Mean	Normal
		P0	P1		
Ca (mg/dl)	Growth	10.43±0.85	11.25±0.89	10.84±0.93	8.00-12.00*
	Lactation	10.06±0.81	10.70±0.14	10.38±0.64	
	Mean	10.25±0.80^{a}	10.98±0.67^{b}		
P (mg/dl)	Growth	6.06±1.11	6.61±1.11	6.33±1.09^{b}	2.48-9.60*
	Lactation	5.10±1.08	5.46±0.93	5.28±0.97^{a}	
	Mean	5.58±1.15	6.03±1.14		

*Purnamaningsih *et al*. (2007)
[a,b]*Means in the same column and row with different letters show significant differences ($p<0.05$), Ca: Calcium, P: Phosphorus, P0: Complete feed without HMB supplementation, P1: Complete feed with HMB supplementation.*

Normal serum Ca (8.00 – 12.00 mg/dL) are according to Purnamaningsih *et al*. (2007) Livestock will absorb calcium minerals according to body needs, if livestock has enough then they will stop absorbing and excess calcium will be disposed of through faeces and urine (Arrizqi, 2020). Calcium similar to phosphorus has functions such as bone and tooth formation, milk production, and fetal development and plays a role in the phosphorylation and oxidation of several important enzymes in the body. The ideal calcium and phosphorus ratio is between 2:1 and 1:1 (Yanuartono *et al*., 2016).

The physiological status had a significant effect (p<0,05) on serum P. Phosphorus requirements in growing lambs are higher to support bone growth, new tissue formation and rapid cell metabolism. Phosphorus is a component of phospholipids that affect cell permeability, ATP transfer, DNA, RNA and enzymatic activity (Ferreira *et al*., 2021). Lactating sheep mobilize a lot of phosphorus for milk production. Phosphorus in milk is used to form important components such as lactose, protein and fat. This leads to decreased phosphorus levels in seum as it is diverted to the mammary glands (Stojkovic *et al*., 2014). The average serum P in livestock is still within normal limits (2.40 – 9.60 mg/dL) (Purnamaningsih *et al*., 2007).

Conclusion

Supplementation of HMB significantly increases serum calcium, which is crucial for bone and teeth development in growing sheep and milk production in lactating sheep. Serum phosphorus is significantly higher in growing sheep, supporting their bone growth and energy metabolism compared to lactating sheep as it is diverted to the mammary gland. Initial and final body weights, average daily weight gain, and feed efficiency are significantly better in growing sheep than in lactating sheep. Hematological profiles and blood metabolites are not affected by HMB supplementation in growing and lactating sheep. Overall levels of hematological profiles and blood metabolites are within the normal range. This indicates that HMB supplementation has a healthful impact on the sheep.

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