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Endocrine and hematobiochemical profile of lambs raised in a semiarid region with different growth potentials during the postweaning period

Shiva Pratap SINGH[1,*], Gopal DASS[2], Ramachandran NATESAN[1], Yogender KUSHWAH[3], Nandini SHARMA[1], Ashok KUMAR[4]

[1]Animal Physiology and Reproduction Division, Indian Council of Agricultural Research -Central Institute for Research on Goats, Makhdoom, Mathura, Uttar Pradesh, India

[2]Goat Genetics and Breeding Division, Indian Council of Agricultural Research - Central Institute for Research on Goats, Makhdoom, Mathura, Uttar Pradesh, India

[3]Nutrition, Feed Resource, and Product Technology Division, Indian Council of Agricultural Research - Central Institute for Research on Goats, Makhdoom, Makhdoom, Mathura, Uttar Pradesh, India

[4]Goat Health Division, Indian Council of Agricultural Research - Central Institute for Research on Goats, Makhdoom, Mathura, Uttar Pradesh, India

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Abstract: This study was conducted for establishment of the relationship of blood variables with growth rate of postweaned lambs. Eight lambs each of fast growth (FG; 11.6 ± 0.5 kg live wt. at weaning) and slow growth (SG; 7.7 ± 0.5 kg live wt. at weaning) were monitored fortnightly for endocrine and hematobiochemical variables along with parasitic load and growth performance. Recording of body weight (BW) and average daily gain (ADG) was performed monthly from birth to 180 days. Triiodothyronine (T3) and thyroxine (T4) were significantly ($P < 0.05$) higher while thyroid-stimulating hormone (TSH) and insulin-like growth factor-1 (IGF-1) were significantly ($P < 0.05$) lower in FG lambs compared to SG lambs. Blood cell counts, hematocrit, hemoglobin, mean corpuscular volume, and mean corpuscular hemoglobin were significantly ($P < 0.05$) higher in FG lambs compared to SG lambs. Except for the birth wt., the BW and ADG of FG lambs were significantly ($P < 0.05$) higher at all time points. Liver enzymes (alkaline phosphatase and alanine aminotransferase) and triglyceride were significantly ($P < 0.05$) higher in SG lambs compared to FG lambs. These findings indicate a significant influence of growth rate on peripheral concentrations of endocrine and some hematobiochemical variables in lambs. These selected variables can be used for early identification and culling of slow-growing lambs for better economic return to lamb producers.

Key words: Endocrine variables, growth potential, hematobiochemical variables, lamb

1. Introduction

The growth rate of lambs during the postweaning period is an important production trait and is affected by the interplay of many factors such as genetic, nutritional, and endocrine factors. Faster growing animals appear to utilize nutrients more efficiently than animals that grow more slowly (1). Many aspects of nutrient utilization and their partitioning are regulated by various hormones such as thyroid hormones triiodothyronine (T3) and thyroxine (T4) (2), and IGF-1 (3), thus having a primary role in regulation of body metabolism and growth. Several studies have confirmed the involvement of thyroid hormones in the metabolic response of animals to certain nutritional, environmental, and/or disease related challenges (3,4). Similarly, IGF-1 is associated with increased somatic growth by mediating anabolic and growth-promoting effects of growth hormone (5).

Blood is an important and reliable medium to estimate the health status of animals, as changes in hematological parameters are often used to determine the level of stress due to environmental, nutritional, and/or pathological factors (6). Thus, results obtained from hematological and blood biochemical studies could be useful in the early selection of animals that are genetically superior and can perform better in terms of growth and production in certain environmental conditions (7).

Gastrointestinal (GI) parasitism, mainly coccidiosis, is one of the most common infections in pre- and postweaning lambs, and clinical signs may range from subclinical weight loss to anemia and diarrhea (8). In addition, parasitism has indirect consequences on metabolism, immune response, reduced feed intake due to anorexia, decreased body growth, and weight loss (9).

* Correspondence: shiva.singh@icar.gov.in

Muzaffarnagari sheep, the heaviest mutton breed, are well adapted to the hot and humid region of the North-western semiarid zone of India. A fast growth rate coupled with high feed conversion efficiency is the main characteristic of this breed (10). However, even after the best management and nutrition, a certain number of animals in the lamb population (6%–10%) grow at an exceptionally low growth rate (11). Early identification and culling of such lambs may help to achieve a better economic return to sheep keepers. Moreover, a better breeding plan in combination with efficient early selection will assist in improvement of a population of better animals in a sheep herd.

To date, however, no comparative information with regards to hematological, biochemical, and endocrine variables of lambs with different growth potentials under similar feeding management is available; therefore, this study aimed to evaluate certain endocrine, hematological, and biochemical variables of lambs of two different levels of growth potential during the postweaning stage and their relationship with the growth parameters of body weight (BW) and average daily gain (ADG). This study will present baseline data for the assessment of growth status of lambs and will be useful in early identification of slow growing lambs in sheep flocks.

2. Materials and methods

2.1. Study site and thermal environment data

This study was carried out at the Indian Council of Agricultural Research-Central Institute for Research on Goats, Makhdoom, Mathura, Uttar Pradesh, 169 m above mean sea level, at 10°N, 78°02′E with a semiarid climate. The wet- and dry-bulb temperatures (°C), ambient temperature (AT, °C), relative humidity (%), maximum – minimum temperature (°C), vapor pressure (mmHg), sunshine (h/day), and temperature humidity index (THI) were recorded three times daily (0900, 1200, and 1700 hours) for the entire experimental period. THI, a measure of heat stress to animals, was calculated from the following formula (12):

$$THI = DB - \{(0.55 - 0.55\ RH)\ (DB - 58)\},$$

where DB is dry-bulb temperature (°C) and RH is relative humidity (%). The obtained THI values were categorized as follows: <82 = absence of heat stress; 82 to <84 = moderate heat stress; 84 to <86 = severe heat stress, and ≥86 = extremely severe heat stress.

2.2. Animals and experimental procedures

Sixteen weaned lambs (116 ± 15 days of age) of the Muzaffarnagari breed were used in the study. Lambs were divided into 2 groups according to their BW at weaning (day 60), i.e. fast growing (FG; n = 8; 4 male and 4 female lambs; weaning weight = 11.6 ± 0.5 kg) and slow growing (SG; n = 8; 4 male and 4 female lambs; weaning weight = 7.7 ± 0.5 kg) lambs. The lambs selected in this study were provided with required suckling during the preweaning stage and it was confirmed that none of them remained underfed with regard to milk requirements.

After weaning, animals were maintained under a semi-intensive feeding management system. Lambs were offered about 150 g of growth ration (concentrate) with adequate dry fodder (gram straw – *Cicer arietinum*; Arhar straw – *Cajanus cajan*) and green fodder (cow pea – *Vigna sinensis*), along with 5-6 h of grazing per day. Nutrient value and detailed composition of feedstuffs offered to the animals is given in Table 1.

Prophylactic measures against sheep diseases like sheep pox, peste des petits ruminants, and enterotoxaemia along with endoparasitic and ectoparasitic infestations were carried out as prescribed by the institute. A feeder and a waterer were placed in each pen and animals were given access to drinking water ad libitum. All the experiments were conducted strictly in accordance with the guideline of the Institutional Animal Ethics Committee.

2.3. Measurements of growth

Body weight of animals was recorded at 30-day intervals from birth to 180 days of age. Slow and fast growing animals

Table 1. Composition of feedstuffs offered to the lambs on dry matter basis.

Constituents, % in DM	Concentrate*	Green fodder	Dry fodder
Organic matter	92.4	87.3	89.3
Crude protein	18.2	22.3	7.7
Ether extract	2.9	2.6	1.7
Neutral detergent fiber	27.9	49.7	57.8
Acid detergent fiber	9.2	35.6	45.9

*Composition of the concentrate: maize (15%), barley (20%), ground nut cake (35%), wheat bran (20%), molasses (7%), mineral mixture (1.5%), and salt (1.5%).

were identified at weaning and used for the experiment. Animals were weighed at 0800 hours, before feeding and watering. Recoding of BW was done by subjecting the animals to stand individually on the weighing machine (Digicontrols Northern Pvt. Ltd., Noida, India). Differences in BW at two consecutive recordings were used to estimate the ADG of animals.

2.4. Blood sample collection

Blood samples were collected at 15-day intervals at the ages of 135, 150, 165, and 180 days by direct jugular venipuncture in tubes with K_2EDTA for hematological studies or without anticoagulant for endocrine and biochemical studies. After clotting, serum samples were collected by centrifugation (600 × *g* for 5 min at room temperature) and the samples were stored at -20 °C until assayed for endocrine and biochemical variables.

2.5. Estimation of blood variables

The hematological analyses were performed with whole blood samples with 3-part-differential using a hematology analyzer (MS4SE, Melet Schloesing Laboratoires, Osny, France). The levels of white blood cells (WBCs), red blood cells (RBCs), hematocrit (Hct), mean corpuscular volume (MCV), hemoglobin (Hb), platelet count, mean platelet volume (MPV), plateletcrit (Pct), platelet distribution width (PDW), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red blood cell distribution width (RDW), and leukocyte differentials, i.e. lymphocytes, monocytes, and granulocytes, were determined.

Serum concentrations of endocrine variables, i.e. T3, T4, thyroid-stimulating hormone (TSH) (all from Calbiotech, Inc., Spring Valley, CA, USA), and IGF-1 (ng/mL) (DRG Instruments GmbH, Marburg, Germany) were estimated using commercial ELISA kits by following the instructions of the manufacturer, and absorbance was recorded by spectrophotometer (SpectraMax plus 384, Molecular Devices, Sunnyvale, CA, USA).

Serum concentrations of biochemical variables, i.e. total protein, albumin, triglyceride, glucose, total cholesterol, urea, and activity of selected liver function enzymes [alkaline phosphatase (ALP), aspartate aminotransferase (AST), alanine aminotransferase (ALT)], were estimated with the help of commercial kits (all from Arkray Healthcare Pvt. Ltd., Gujrat, India) by following the instructions of the manufacturer.

2.6. Worm load

Fecal samples from all the lambs were collected at the start and at the end of the trial, at the 1st (day 0) and final sampling (day 45), to assess the difference in worm load. Fecal eggs/oocysts counts were carried out on freshly collected fecal samples using centrifugal floatation in saturated salt (NaCl) solution using the modified McMaster technique (13), which were expressed as eggs/oocysts per gram (EPG/OPG) of feces.

2.7. Statistical analyses

Data were first tested for normal distribution using the Kolmogorov–Smirnov test and homogeneity of variances was tested using the Levene test. The mixed model procedure was used for each serum endocrine variable as a dependent variable. Growth type (fast or slow growth) and days were considered as fixed factors and sampling days as repeated effects, and their respective interactions were included in the model. The covariance structure, i.e. repeated covariance type autoregressive (order-1), followed by Bonferroni correction were used for serum endocrine data. Differences in growth parameters (birth weight, weaning weight, live BW) and pooled hematological and biochemical parameters among the groups were compared by independent samples t-test. Meteorological parameters at 3 different time points were analyzed using one-way ANOVA with post hoc Tukey multiple comparisons. Pearson correlations (2-tailed) were calculated between BW or ADG and blood (endocrine and hematological) variables. The data on fecal egg/oocyst counts were transformed logarithmically and the resulting transformed variables were tested for normality before analysis. The most appropriate transformation $\log_e$ (FEC + 100) was used to correct for heterogeneity of variance and to produce approximately normally distributed data. The results were back-transformed by taking the antilogarithms of means, subtracting 100, and presented as geometric means (GFEC). The GFEC data were subjected to the GLM procedure to find a significant difference between the 2 growth levels, 3 parasitic types, and 2 sampling periods. Statistical analyses were performed using SPSS (version 16.0, SPSS Inc., Chicago, IL, USA). All data are presented as arithmetic means ± standard error of the mean (mean ± SEM) and probability values (P) lower than 0.05 were considered to be statistically significant.

3. Results

3.1. Meteorological variables and live body weight

Values of the meteorological variables during the study period are presented in Table 2. The results indicate significantly ($P < 0.05$) higher AT and THI during the afternoon compared to morning and evening (Table 2). Mean values of THI indicated stressful weather conditions during morning (83.8 ± 0.3), afternoon (87.0 ± 0.3), and evening (85.7 ± 0.3). Mean maximum temperature (°C), minimum temperature (°C), mean daily temperature (°C), and sunshine hours (h) during the study were 37.8 ± 0.3 (34.0-40.5), 26.4 ± 0.2 (24.0-29.0), 32.1 ± 0.2 (30.0-34.3), and 7.7 ± 0.4 (2.7-11.1), respectively.

The changes in live BW (kg) of animals of both groups from birth to 180 days of age are illustrated in Figure 1.

Table 2. Meteorological variables during the period of study.

Meteorological variable	Time			Mean
	0900 hours	1200 hours	1700 hours	
AT (°C)	31.4 ± 0.3[a]	35.2 ± 0.4[b]	34.1 ± 0.4[bc]	33.6 ± 0.3
RH (%)	72.6 ± 2.0[a]	61.3 ± 2.4[b]	62.2 ± 2.6[b]	65.4 ± 2.2
THI	83.8 ± 0.3[a]	87.0 ± 0.3[b]	85.7 ± 0.3[c]	85.5 ± 0.2
VP (mmHg)	24.9 ± 0.5	25.3 ± 0.6	24.3 ± 0.6	24.8 ± 0.5

AT = Ambient temperature; RH = relative humidity; THI = temperature humidity index; VP = vapor pressure.
a, b, c: Means in the same row with different superscripts differ significantly (P < 0.05).

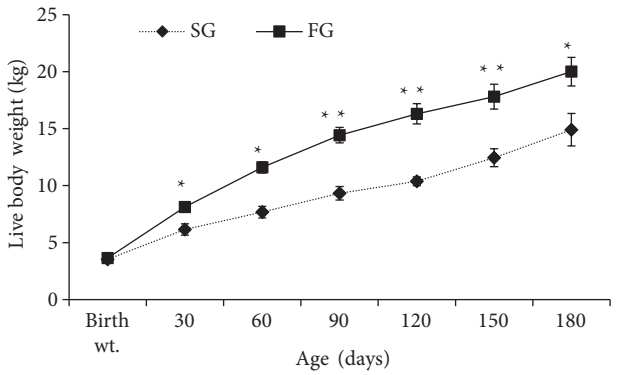

Figure 1. Live body weight (kg) of fast growing (FG) and slow growing (SG) lambs at birth and during the first 6 months of life (*: P < 0.05; **: P < 0.01).

Birth weight (kg) was statistically similar in the two groups (3.7 ± 0.1 vs 3.5 ± 0.1); however, from the first month onwards, significantly (P < 0.05) higher BW was observed in FG lambs compared to SG lambs at all time points. Growth variables at different stages of time for lambs of both the groups during the pre- and postweaning periods are presented in Table 3. The ADG (g/day) from birth to weaning (FG lambs: 119.7 ± 7.7; SG lambs: 64.4 ± 6.4; P < 0.05), weaning to 6 months of age (FG lambs: 61.9 ± 8.4; SG lambs: 49.2 ± 7.1; P < 0.05), and for the total period (FG: 90.8 ± 7.3; SG: 63.1 ± 8.1; P < 0.05) was significantly higher in FG lambs compared to SG lambs (Table 3).

3.2. Endocrine variables

Differences in the serum endocrine variables (T3, T4, TSH, and IGF-1) of both FG and SG groups at different time points during the postweaning period are presented in Figure 2. Serum concentrations of T3 (ng/mL) and T4 (ng/mL) were significantly (P < 0.01) higher in FG lambs (3.0 ± 0.2 and 9.2 ± 0.5) compared to SG lambs (1.9 ± 0.1 and 6.7 ± 0.26). In contrast to this, significantly higher serum concentrations of TSH (ng/mL; P = 0.036) and IGF-1 (ng/mL; P = 0.008) were observed in SG animals (12.6 ± 1.8 and 116.8 ± 5.1) compared to FG animals (5.2 ± 0.9 and 92.2 ± 5.5). The T3:T4 ratio in FG and SG animals was 0.44 ± 0.03 and 0.3 ± 0.02, respectively. A significant positive correlation of BW was observed with T3 (r = 0.356; P = 0.004) and T4 (r = 0.337; P = 0.006), whereas BW was inversely correlated with TSH (r = –0.394; P = 0.001).

3.3. Hematological and biochemical variables

The changes in hematological variables of both the groups at different time points are shown in Table 4. Blood cell counts (WBCs and RBCs) were significantly (P < 0.05) higher in FG lambs compared to SG lambs. However, leukocyte differentials (lymphocytes, monocytes, and granulocytes) were similar between the groups (P > 0.05).

Table 3. Growth variables in fast growing (FG) and slow growing (SG) lambs during the study.

Group	Type of birth[#]	Sex of the lambs	Birth weight (kg)	Weaning weight (kg)*	Weight at the start of blood sampling (kg)**	Weight at the end of study (kg)	ADG (g/day)***
FG	4 singletons and 4 twins	4 males and 4 females	3.7 ± 0.1	11.6 ± 0.5[a]	15.9 ± 0.9[a]	20.0 ± 1.3[a]	90.8 ± 7.3[a]
SG	4 singletons and 4 twins	4 males and 4 females	3.5 ± 0.1	7.7 ± 0.5[b]	10.3 ± 0.6[b]	14.9 ± 1.4[b]	63.2 ± 8.1[b]

a, b: Means in the same column with different superscripts differ significantly (P < 0.05).
[#] Age of the dams ranged from 2.5 to 3 years.
* Weaning of lambs was done at 2 months of age.
Average daily gain (ADG) = live weight gain (g/day).
** At 135 days of age.
*** From birth to 180 days of age.

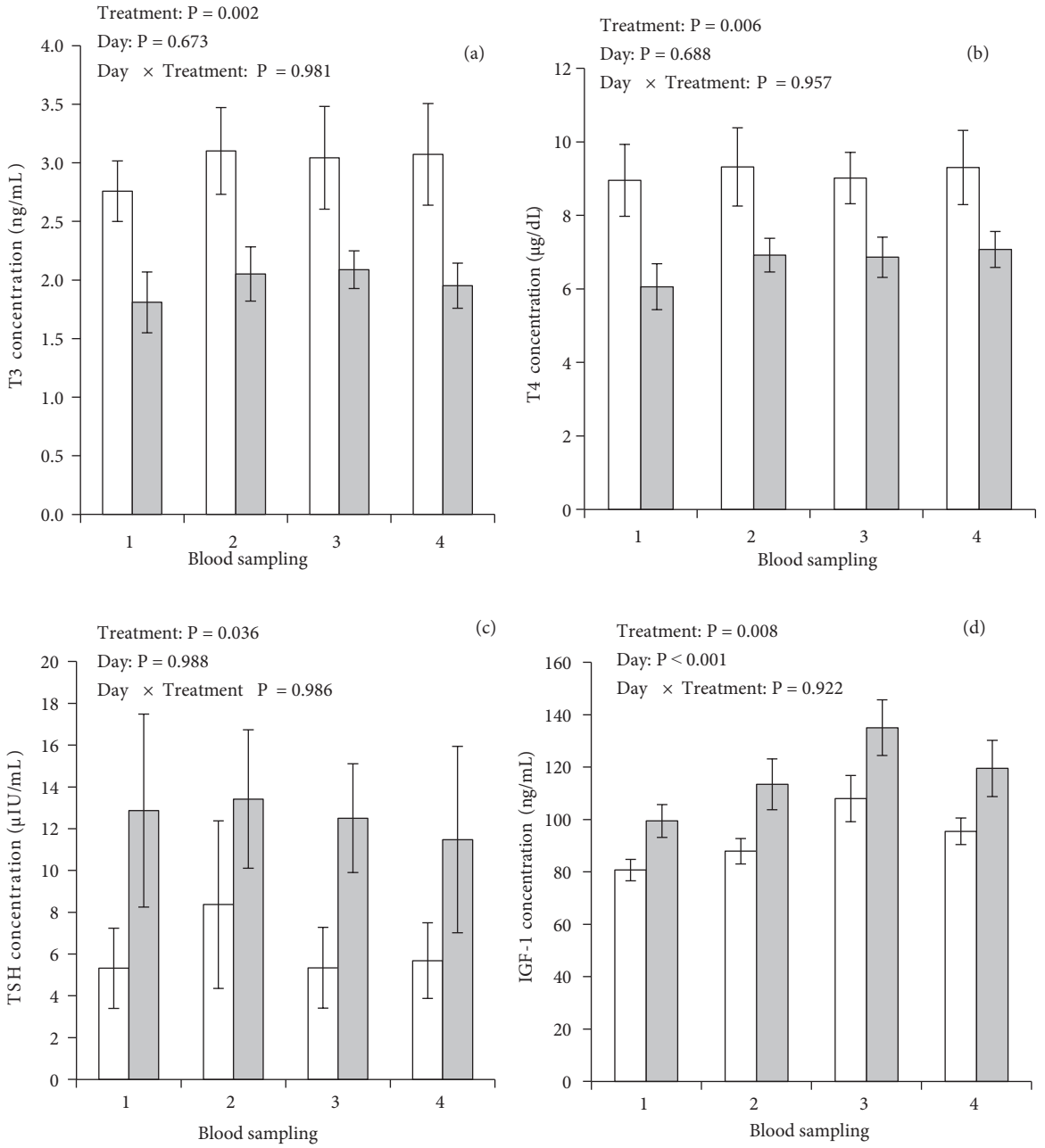

Figure 2. Endocrine variables [triiodothyronine (T3; a), thyroxine (T4; b), thyroid-stimulating hormone (TSH; c), and insulin-like growth factor (IGF-1; d)] of fast growing (FG, white bars) and slow growing (SG, gray bars) lambs on different sampling days of the postweaning period. Blood samplings 1, 2, 3, and 4 represent the collection of blood samples at 135, 150, 165, and 180 days of age, respectively.

Values of Hct and Hb were significantly ($P < 0.05$) higher in FG animals compared to SG animals. The plateletcrit (Pct) or thrombocrit value is the proportion (%) of whole blood occupied by platelets. No difference was observed in Pct of the groups (Table 4). A significant positive correlation of BW was observed with WBC count ($r = 0.320$; $P = 0.010$), RBC count ($r = 0.359$; $P = 0.004$), Hb ($r = 0.388$; $P = 0.002$), and MPV ($r = 0.302$; $P = 0.015$).

Biochemical variables of both groups at different time points are presented in Table 5. Elevated concentrations of liver enzymes (ALT and ALP) and triglyceride were observed in SG compared to FG animals ($P < 0.05$), whereas albumin concentration was significantly ($P = 0.019$) lower in SG compared to FG animals.

Table 4. Hematological variables during the study period in fast growing (FG) and slow growing (SG) lambs at different time points.

Variables	Group	Blood sampling*				Mean	P-value
		d 135	d 150	d 165	d 180		
WBC ($\times 10^3/mm^3$)	FG	12.3 ± 1.5	15.5 ± 2.2	16.3 ± 2.5	16.2 ± 1.1	15.1 ± 1.0	0.027
	SG	10.4 ± 0.6	14.3 ± 1.3	11.6 ± 0.4	13.3 ± 1.7	12.4 ± 0.6	
RBC ($\times 10^6/mm^3$)	FG	9.8 ± 0.3	9.1 ± 0.3	8.9 ± 0.4	8.5 ± 0.4	9.1 ± 0.2	<0.001
	SG	8.3 ± 0.3	7.9 ± 0.3	8.0 ± 0.3	7.9 ± 0.5	8.0 ± 0.2	
Hct (%)	FG	26.1 ± 0.5	24.6 ± 0.7	24.0 ± 0.8	23.2 ± 0.9	24.5 ± 0.4	0.018
	SG	24.1 ± 0.5	23.0 ± 0.6	23.5 ± 0.6	23.4 ± 1.1	23.5 ± 0.4	
MCV (fL)	FG	26.9 ± 0.6	27.2 ± 0.6	27.2 ± 0.6	27.4 ± 0.5	34.9 ± 7.7	<0.001
	SG	29.3 ± 0.6	29.4 ± 0.5	29.4 ± 0.4	29.9 ± 0.6	29.5 ± 0.3	
Hb (g/dL)	FG	6.1 ± 0.2	7.9 ± 0.3	7.8 ± 0.3	7.6 ± 0.4	7.6 ± 0.2	0.001
	SG	6.2 ± 0.2	7.5 ± 0.3	7.6 ± 0.2	7.5 ± 0.4	7.2 ± 0.2	
Platelets ($\times 10^3/mm^3$)	FG	203.9 ± 45.1	330.1 ± 65.4	304.0 ± 35.7	180.0 ± 50.9	254.5 ± 26.6	0.482
	SG	182.3 ± 22.2	296.3 ± 40.5	356.1 ± 26.6	277.9 ± 46.8	278.1 ± 20.3	
MPV (fL)	FG	4.9 ± 0.1	6.7 ± 0.2	6.4 ± 0.1	6.8 ± 0.2	6.2 ± 0.2	0.026
	SG	4.9 ± 0.03	6.4 ± 0.1	6.2 ± 0.1	5.9 ± 0.3	5.9 ± 0.1	
Pct (%)	FG	0.15 ± 0.04	0.21 ± 0.04	0.20 ± 0.02	0.12 ± 0.03	0.17 ± 0.02	0.445
	SG	0.17 ± 0.08	0.19 ± 0.03	0.22 ± 0.02	0.17 ± 0.03	0.19 ± 0.02	
PDW (%)	FG	5.4 ± 0.8	6.8 ± 0.8	7.9 ± 0.6	6.1 ± 1.5	6.5 ± 0.5	0.974
	SG	6.8 ± 0.3	7.2 ± 0.5	6.3 ± 0.3	5.9 ± 1.0	6.54 ± 0.3	
MCH (pg)	FG	7.1 ± 0.2	8.7 ± 0.1	8.68 ± 0.1	8.81 ± 0.8	8.3 ± 0.1	0.006
	SG	7.5 ± 0.1	9.5 ± 0.2	9.39 ± 0.1	9.50 ± 0.2	8.9 ± 0.2	
MCHC (g/dL)	FG	26.8 ± 0.3	32.4 ± 0.5	36.2 ± 3.6	32.6 ± 0.5	31.9 ± 1.1	0.757
	SG	25.8 ± 0.3	32.5 ± 0.6	35.8 ± 3.8	31.9 ± 0.2	31.5 ± 1.1	
RDW (%)	FG	13.9 ± 0.4	14.2 ± 0.3	14.2 ± 0.4	12.1 ± 0.7	18.6 ± 4.7	0.279
	SG	13.7 ± 0.4	13.4 ± 0.6	13.3 ± 0.6	13.6 ± 0.4	13.5 ± 0.2	
LYM (%)	FG	37.4 ± 2.8	43.4 ± 5.4	41.5 ± 4.3	49.1 ± 3.8	42.8 ± 2.1	0.242
	SG	38.5 ± 1.8	39.1 ± 3.9	33.9 ± 3.3	46.2 ± 5.3	39.4 ± 1.9	
MON (%)	FG	6.8 ± 0.3	4.3 ± 0.4	4.0 ± 0.3	3.9 ± 0.2	4.8 ± 0.3	0.533
	SG	7.5 ± 0.1	4.1 ± 0.6	4.5 ± 0.3	3.9 ± 0.4	5.0 ± 0.3	
GRA (%)	FG	55.9 ± 2.9	52.2 ± 5.2	54.5 ± 4.3	47.1 ± 3.8	52.4 ± 2.1	0.248
	SG	54.0 ± 1.9	57.2 ± 3.7	61.6 ± 3.2	49.9 ± 5.0	55.68 ± 1.9	

WBC = White blood cells, RBC = red blood cells, Hct = hematocrit, MCV = mean corpuscular volume, Hb = hemoglobin, MPV = mean platelet volume, Pct = plateletcrit, PDW = platelet distribution width, MCH = mean corpuscular hemoglobin, MCHC = mean corpuscular hemoglobin concentration, RDW = red blood cell distribution width, LYM = lymphocytes, MON = monocytes, GRA = granulocytes.

* Blood samplings represent collection of blood samples at the ages of 135, 150, 165, and 180 days.

Table 5. Biochemical and enzymatic variables during the study period in fast growing (FG) and slow growing (SG) lambs at different time points.

Variables	Group	Blood sampling*				Mean	P-value
		d 135	d 150	d 165	d 180		
Total protein (g/dL)	FG	5.3 ± 0.2	5.7 ± 0.1	6.2 ± 0.2	6.0 ± 0.1	5.8 ± 0.1	0.658
	SG	5.4 ± 0.1	5.8 ± 0.2	6.2 ± 0.1	6.2 ± 0.1	5.9 ± 0.1	
Albumin (g/dL)	FG	2.7 ± 0.3	3.0 ± 0.1	2.3 ± 0.1	2.6 ± 0.1	2.7 ± 0.1	0.019
	SG	2.1 ± 0.2	2.9 ± 0.1	1.9 ± 0.3	2.3 ± 0.2	2.3 ± 0.1	
Triglycerides (mg/dL)	FG	57.3 ± 0.9	60.1 ± 0.7	66.1 ± 1.4	69.4 ± 0.7	63.2 ± 1.6	0.040
	SG	58.2 ± 0.8	71.4 ± 1.1	68.2 ± 0.9	74.4 ± 1.1	68.1 ± 1.7	
Glucose (mg/dL)	FG	63.8 ± 1.6	65.0 ± 0.1	60.1 ± 0.6	63.3 ± 0.1	63.1 ± 1.5	0.112
	SG	58.5 ± 0.1	67.2 ± 0.1	57.2 ± 0.4	56.7 ± 0.5	59.9 ± 1.3	
Total cholesterol (mg/dL)	FG	66.6 ± 0.9	66.7 ± 0.7	64.7 ± 0.4	68.9 ± 0.3	66.1 ± 0.9	0.265
	SG	62.9 ± 0.8	69.2 ± 1.1	71.4 ± 0.1	70.7 ± 0.7	68.5 ± 1.3	
Urea (mg/dL)	FG	33.1 ± 0.9	38.4 ± 1.1	52.4 ± 0.7	51.4 ± 0.5	43.8 ± 1.8	0.330
	SG	37.9 ± 0.7	40.3 ± 0.7	52.7 ± 0.1	54.4 ± 1.1	46.3 ± 1.8	
ALP (KA units)	FG	7.4 ± 0.4	12.5 ± 0.1	6.0 ± 0.5	12.8 ± 0.8	9.7 ± 1.1	0.010
	SG	8.2 ± 0.9	21.2 ± 1.3	12.5 ± 0.8	18.8 ± 1.4	15.2 ± 1.8	
AST (IU/L)	FG	118.3 ± 2.1	122.5 ± 5.0	96.0 ± 2.3	167.8 ± 3.3	126.2 ± 6.5	0.134
	SG	128.5 ± 11.5	119.1 ± 6.0	140.6 ± 2.2	194.6 ± 6.1	145.7 ± 11.1	
ALT (IU/L)	FG	10.5 ± 1.4	9.6 ± 1.5	13.2 ± 2.3	11.3 ± 1.4	11.1 ± 0.8	0.005
	SG	16.0 ± 2.4	13.9 ± 1.6	15.4 ± 3.6	18.6 ± 3.8	16.0 ± 1.4	

ALP = Alkaline phosphatase, AST = aspartate aminotransferase, ALT = alanine aminotransferase.
* Blood samplings represent collection of blood samples at the ages of 135, 150, 165, and 180 days.

3.4. Worm load

Fecal eggs/oocysts counts of lambs of two levels of growth potentials at the time of the start of the experiment and at the end of blood sampling are presented in Table 6. Total parasitic load (including coccidial infection and others, i.e. tapeworms and bursate nematodes), sampling period, type of oocysts/eggs, and their interactions were not significantly ($P > 0.05$) different among the groups.

4. Discussion

In order to achieve a better economical return, selection of animals with relatively better growth potential at an early age is important. The present study demonstrated the comparison of some hormonal, hematological, and biochemical variables in lambs with different growth rates and their relationship with BW during the postweaning period. The thermal environmental observations during the study were characterized by high AT and THI, typical of the hot-dry period in the semiarid region of northern India. Values of THI over 86 are considered as indicative of severe to extreme heat stress, while values below 82 indicate the absence of heat stress (12). Lambs in the present study were under severe heat stress during the afternoon, as the THI at this time varied between 83.52 and 89.62. Overall, meteorological conditions during the study were unfavorable to the lambs when THI attained the peak value mainly during hot hours of the day. The effects of elevated AT on growth performance of animals are reported, as this is mainly the pooled effect of decline in anabolic activities and increase in tissue catabolism (12). Therefore, to avoid any deviation in blood variables and growth performance due to heat stress, animals of both groups were maintained in similar barns with proper provision of floor space and ventilation. The stress caused by weaning is observed as a major factor that affects the growth rate of lambs after weaning (14,15). Therefore, the reduced ADG of both the groups during the postweaning period, i.e. from day 60 to day 135 (57.5 g and 34.3 g), compared to the ADG during the trial, i.e. from day 135 to day 180 (91 g and 102 g), may be due to weaning stress to the lambs.

After release from adenohypophysis, TSH stimulates the thyroid gland to produce and release thyroid hormones (both T3 and T4) that regulate growth, differentiation,

Table 6. Mean ± SD for logarithmic fecal oocyst/egg count* (LFOC/ LFEC) [$\log_e$ (FOC or FEC + 100)] of lambs under different levels of growth potential [slow growing (SG) and fast growing (FG)] at 2 sampling dates (day 135 and day 180).

Type of parasitic oocysts/eggs	Fecal sampling	SG	FG	Overall
Coccidia	Day 135	4.6 ± 0.02 (750)	4.7 ± 0.06 (1625)	4.7 ± 0.05 (1188)
	Day 180	4.6 ± 0.02 (575)	4.6 ± 0.01 (450)	4.6 ± 0.01 (513)
	Mean	4.7 ± 0.04 (1181)	4.7 ± 0.05 (1268)	4.7 ± 0.05 (1225)
Tape worm	Day 135	4.6 ± 0.03 (450)	4.6 ± 0.01 (75)	4.6 ± 0.02 (263)
	Day 180	4.6 ± 0.02 (275)	4.6 ± 0.00 (0)	4.6 ± 0.02 (138)
	Mean	4.7 ± 0.08 (887)	4.6 ± 0.04 (225)	4.6 ± 0.06 (556)
Bursate nematodes	Day 135	4.6 ± 0.03 (750)	4.7 ± 0.16 (2450)	4.7 ± 0.12 (1600)
	Day 180	4.7 ± 0.07 (1150)	4.6 ± 0.03 (825)	4.7 ± 0.05 (988)
	Mean	4.7 ± 0.06 (1206)	4.7 ± 0.10 (1443)	4.7 ± 0.08 (1325)
Overall	Day 135	4.6 ± 0.03 (650)	4.7 ± 0.10 (1383)	4.7 ± 0.08 (1017)
	Day 180	4.6 ± 0.04 (666)	4.6 ± 0.024 (425)	4.6 ± 0.03 (546)
	Mean	4.7 ± 0.06 (1091)	4.7 ± 0.07 (979)	4.7 ± 0.07 (1035)

* Units eggs/g.
Value in parentheses indicates the geometric fecal oocyst/egg count (GFOC/GFEC).
P-values: Growth levels, $P = 0.610$; sampling periods, $P < 0.009$; type of parasitic oocysts/eggs, $P < 0.035$; growth levels × type, $P = 0.152$; growth levels × stage, $P = 0.205$; type × sampling periods, $P = 0.749$; growth levels × sampling periods × type of parasitic oocysts/eggs, $P < 0.854$.

and energy balance. Therefore, increased TSH is the most sensitive test for the diagnosis of decreased activity of the thyroid gland in humans and animals (16). This study has demonstrated that serum concentrations of TSH, thyroid hormones (T3 and T4), and IGF-1 in lambs were affected by their growth rate (Figure 2). The concentrations of TSH and thyroid hormones observed in the study are in agreement with the values reported elsewhere (17). The observed effects of growth rate on lamb serum thyroid hormone concentrations are in agreement with the findings of Van Kessel et al. (18). In contrast to this, Antunovic et al. (19) did not observe a significant difference in thyroid hormone concentrations in lambs before and after weaning when growth rates were different. We observed a significant positive correlation of thyroid hormones with BW and ADG. Similarly, plasma T4 is observed to be positively correlated with larger body size and enhanced growth in Suffolk ewes (20).

IGF-1 is a pleiotropic growth factor that acts on many tissues to regulate growth by both cellular replication and differentiated functions. Association between serum IGF-1 and growth is most likely due to the role of IGF-1 in enhanced stimulation of long bone growth, increased nutrient availability (21), and muscle tissue accretion (22). Therefore, a lower concentration of IGF-1 hormone in SG lambs was expected compared to FG lambs (23). In contrast to this, we observed significantly higher concentrations of this hormone in SG animals (Figure 2). Significantly higher concentration of TSH in SG animals may be the reason for higher IGF-1 in this group as TSH has stimulatory effects on growth hormone secretion from the anterior pituitary (24), which may subsequently stimulate IGF-1 production by hepatocytes. Higher IGF-1 concentration in SG lambs may be of physiological importance for improving the growth rate of such animals.

The low value of the correlation coefficient between IGF-1 concentration and BW of both the groups ($r = 0.210$; $P = 0.110$) is in agreement with earlier study on lambs (25). This may be due to high variability in IGF-1 concentration compared to the changes in the BW of the animals (25). Therefore, the measurement of plasma IGF-1 is unlikely to be an effective aid for selection of lambs with high growth rate. However, these results differ from an earlier study in which a relationship of IGF-1 with BW appeared to exist (26).

An understanding of hematological characteristics is an important tool that can be used as a sensitive index to monitor health status and physiological changes in farm animals. Differences in some hematological parameters that were observed between the groups could be attributed

to differences in their growth pattern and endocrine parameters. However, the values of blood cell differentials of lambs in the present study are largely in agreement with the earlier reports (27,28). High RBC count in lambs of both groups compared to adult values is in agreement with an earlier study (29). This may be due to release of more RBCs into circulation by increased release of adrenaline and ACTH as a result of exposure to high AT (30) and more excitement during handling in young animals compared to adult animals (31). MCV, MCH, and MCHC are related to individual RBC count and are important parameters for the diagnosis of anemia. Significantly lower RBC count, Hb concentration, and MCV, along with significantly higher MCH, indicated an anemic condition in SG lambs. An increase in MCH in SG lambs compared to FG lambs could have resulted from a greater degeneration of RBCs (28), which may have occurred due to unknown reasons in SG lambs.

Indices of platelets including platelet count, PDW, Pct, and MPV are being used in routine health examination of humans; however, their use and application in growth studies of farm animals remain unknown. Platelet count in the two groups was not different (P = 0.482) and the mean values were about 1.5- to 2.0-fold lower compared to adult sheep (32). RDW and PDW are indicators of heterogeneity in the size of RBCs and platelets, respectively. Platelet distribution width is a more specific indicator of platelet activation than MPV, since it is not elevated during single platelet distention caused by platelet swelling and thus the combined use of MPV and PDW could predict activation of coagulation more efficiently (33). Absence of difference in PDW between the groups suggests no effect of growth rate on platelet activation in lambs. The reasons for an absence of differences in other hematological variables of both groups are unclear but may be related to altered patterns of growth and hormonal variables of SG and FG lambs.

Recently it was reported that serum biochemistry is a useful tool in the clinical diagnosis of various systemic states and growth performance of lambs (34). We have observed significantly higher blood concentrations of ALT and ALP in SG lambs compared to FG lambs. As reported earlier for poultry birds (35), higher levels of these enzymes in SG lambs indicates that liver metabolism is affected in response to the growth performance of lambs.

Young animals are more prone to internal parasites, as lambs of 2-5 months of age are most commonly affected by coccidiosis, in addition to other minor parasitic infections. Absence of differences in worm load, including coccidian oocysts, of the two groups in the present study may be due to proper housing in terms of sufficient floor space and separate housing for lambs and adult sheep along with common prophylactics adapted on the sheep farm. Thus, the observed difference in growth clearly indicates that lowered growth of SG animals is not due to internal parasitic load, as reported earlier (9), but rather that some other factors, such as hormones related to the growth of animals (thyroid hormones and IGF-1), are more associated with this difference in the present experimental conditions.

In conclusion, the results of the present study revealed that, under similar feeding management conditions, growth rate had marked effects on certain endocrine (T3, T4, TSH, and IGF-1), hematological (RBC, WBC, Hct, MCV, Hb, MPV, and MCH), and biochemical (AP, ALT, triglyceride, and albumin) variables of lambs raised in a tropical semiarid region. This suggests that the investigation of growth potential of postweaning lambs can be accomplished with these endocrine, hematological, and biochemical variables (all those differing between the groups), individually or in combination, due to their predictive importance for selection of lambs at an early age. Selection and culling of slow growing lambs at an early age may provide better economic returns to sheep producers. Further in-depth comprehensive studies in controlled experiments are needed to verify the relationship of nutrition, growth, parasitic load, and metabolic hormones of lambs raised in different climatic conditions.

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