Factors Affecting Hematological Profiles in Three Ethiopian Indigenous Goat Breeds

M. Tibbo, DVM[a]
Y. Jibril, DVM[b]
M. Woldemeskel, DVM, PhD[b]
F. Dawo, DVM, MVSc[c]
K. Aragaw, DVM[a]
J.E.O. Rege, BSc, MS, PhD[d]

[a]*Sheno Agricultural Research Centre, Debre Berhan, Ethiopia*
[b]*Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit, Ethiopia*
[c]*Adami-Tulu Research Centre, Animal Health Division, Zeway, Ethiopia*
[d]*International Livestock Research Institute (ILRI), Animal Genetic Resources, Addis Ababa, Ethiopia*

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ABSTRACT

Hematological parameters were studied in 163 apparently healthy goats comprised of 3 indigenous breeds at Adami-Tulu Agricultural Research Centre (ATARC) and Sheno Agricultural Research Centre (SARC), Ethiopia. Data were analyzed for the effect of breed, sex, age, and season. Hemoglobin (Hb) was significantly higher ($P<0.0001$) for Arsi-Bale (AB) than Long-eared Somali (LES) and Central Highland (CH) goats. Packed cell volume (PCV) was significantly lower ($P<0.0001$) for LES than the other two breeds. White blood cells (WBC) ($P<0.05$), neutrophils ($P<0.0001$) and basophils ($P<0.0001$) were higher in CH than in the other two breeds. Conversely, lymphocytes were lowest ($P<0.0001$) in CH goats compared to other breeds. Female goats had significantly (at least $P<0.05$) higher red blood cells (RBC), PCV, WBC, lymphocytes and eosinophils than male goats. In contrast, males had higher ($P<0.05$) mean corpuscular hemoglobin (MCH) and neutrophils than females. There was no significant age difference for the erythrocytic series but the age difference was highly significant ($P<0.0001$) for the leukocytic series. WBC and lymphocytes decreased as age increased while the reverse was true for neutrophils and eosinophils. Seasonal variation was also considerable for both erythrocytic and leukocytic series. RBC, Hb, lymphocytes, and neutrophils of the indigenous goat breeds were remarkably different compared to most other exotic goat breeds.

INTRODUCTION

Ethiopia hosts 23,325 million goats.[1] Despite their value to society as a source of milk, meat, cash, and security, goat research and development was neglected for many years. The integration and full utilization of goats is constrained by various factors including high prevalence of diseases, low genetic potential and plane of nutrition, poor management, and extensive production systems.[2] Of these factors, diseases are rampant and have a significant impact on the performance of animals. Proper diagnosis is a pre-requisite for health interventions (treatment, control or prevention).

Hematological tests have been widely used for the diagnosis of various animal diseases. The information gained from the blood parameters would substantiate the physical examination and coupled with medical history provide excellent basis for medical judgment.[3] In addition, it would help determine the nature of the disease, the extent of tissue and organ damage, the response of the defense mechanism of the patient, and aid in diagnosing the type of possible anemia.[3] It would also prove useful in evaluating patients before commencing any surgical intervention and selecting appropriate treatment.[3] A quantifiable variation was reported in blood parameters due to altitude, management, feeding level, age, sex, breed, health status, method of blood collection, hematological techniques used, diurnal and seasonal variation, ambient temperature, and physiological status (excitement, muscular exercise, pregnancy, estrus, parturition, time of sampling, water balance and transportation).[3,4,5]

Although clinical hematology is a potentially valuable diagnostic aid in the health care of animals, the interpretation of results in sick animals is often difficult. Physiologic and pathological changes can be best evaluated when normal values are available for comparison. Even though considerable information is available on the normal blood parameters of domestic animals, the values are that of exotic goat breeds kept under different environment and management conditions. This paper reports the effects of breed, age, sex, and season on hematological values of 3 indigenous goat breeds of Ethiopia.

MATERIALS AND METHODS

Study Area

The study was conducted between November 1999 and April 2001 at Adami-Tulu Agricultural Research Centre (ATARC) and Sheno Agricultural Research Centre (SARC), Ethiopia. ATARC is situated in the mid-rift valley at 7˚9'N latitude, 38˚7'E longitude, and 167 km south of Addis Ababa, Ethiopia. It has an altitude of 1650 meters above sea level with a bimodal unevenly distributed rainfall. An unpublished 10 years data of ATARC (1998) shows that average annual rainfall was 760.9 mm and consisted of short rainy season (February to April) and long rainy season (July to September). Minimum and maximum mean temperatures were 12.7˚C and 27.2˚C, respectively, with a relative humidity of 60%. Natural pasture, the major feed resources of livestock, is composed of predominantly grasses (Pennisetum, Cenchurus, Sporobulus, Aestida, and Hyperhenia) and legumes (*Crotalaria spp*.).

SARC is situated in the central plateau of Ethiopia at an altitude of 2800 m above sea level, latitude 07˚10'N and longitude 39˚21'E, and at about 70 km north–east of the capital city, Addis Ababa. The mean annual rainfall from 1988 to 1997 was 945.4 mm with bimodal rainfall pattern: a long rainy season that extends from June to September and a short one from February to May. The area has a mean maximum and minimum temperature of 18.5˚C and 6.1˚C, respectively, with a relative humidity of 68.7%. Frost occurs usually between the months of October and January. The natural pasture is dominated by *Andropogon abssynicus* and *Sporobolus africanus* with a varying proportion of *Trifolium spp*.

Animals and Management

A total of 163 goats composed of indigenous Arsi-Bale (AB), Central Highland (CH) and Long-eared Somali (LES) breeds of different age and sex classes were used (Table 1). Central Highland goats were studied at SARC whereas AB and LES breeds at ATARC. The breeds, which are indigenous to Ethiopia, have been described earlier.[6] Briefly, the AB, locally named as Gishe and Sidama, are part of the rift valley family and distributed throughout the Arsi and Bale regions, up to an altitude of 4000 meters above sea level. These goats are also found in the higher altitudes of Sidamo, Western Harargie and occupy all the agro-pastoral lowlands within the rift valley from Lake

Abaya in the south, to south Shoa in the north in Ethiopia. Generally, they are adapted to humid, sub-humid highlands and the semi-arid areas of Arsi, Bale and Sidamo. The CH, often locally named brown goats, are categorized under Small East African family. They are distributed in the central highlands of Ethiopia west of the Rift Valley escarpment in central Tigray, Wello, Gondar, and North Shoa. Different from other breeds of goats, they are highly adapted to cool tropical environments locally known as *Dega* and *Woina Dega* at a higher altitude. The LES are classified as part of the Somali family, locally named as large-white Somali, *Degheir*, *Galla*, *Digodi* and *Melebo*, and probably descended from the Arab goats in Somalia. The goats are distributed throughout the Ogaden, lowlands of Bale, Borana, and Southern Sidamo. They are adapted to arid (*Bereha*) and semi-arid (dry *Kolla*) agro-climatic zones, and kept by pastorals of the Hawia, Ogaden, Rare-bare, Digodi clans of the Somali and Boran, Gabra and Geri ethnic groups.

Table 1. Profiles of Study Goats

Breed	Sex	Age group			Total
		>12 to ≤24	>24 to ≤36	>36	
Arsi-Bale	Female	11	9	14	34
	Male	7	2	15	24
Central highland	Female	4	6	19	29
	Male	8	3	6	17
Long-eared Somali	Female	9	8	11	28
	Male	8	2	9	19
	Total	47	30	74	151

The feeding program was mainly free grazing, where the goats were released to free-graze on rangelands at ATARC and on-station natural pastures at SARC, and watered *ad libitum* from watering troughs. No supplementation was given during the study period.

At ATARC, as part of routine activities, all weaned and adult goats were vaccinated against anthrax, pasteurellosis and goat pox (National Veterinary Institute, Ethiopia), as a prevention and control package against these infectious diseases. Regular monthly spraying of acaricides against ectoparasites was performed throughout the study period. The acaricides used were Chlorfenvinphos (Steladone, Ciba-Geigy Ltd, Basle, Switzerland), Ethion (Cethion, Cheminova Agro A/S, Denmark) and Amitraz (Mill House, Coventry, UK). To avoid the confounding effect of parasitism on normal blood values, the study animals were dewormed at 3-month intervals with 2.5% Albendazole (Laboratorios Hipra, S.A., Amer, Girona, Spain).

At SARC, the vaccination regime was similar to that of ATARC. Animals were dewormed using fenbendazole (Panacur, Hoechst UK Ltd, UK) at the start of the experiment, and 4 times a year according to the recommendations[7] in late June, mid–July, early September, and October. In September, mid–November, late December, and early February, they also received triclabendazole (Fasinex, Ciba-Geigy Ltd., Switzerland) to control trematodes. For protection from ectoparasites, they were sprayed with chlorfenvinphos (Steladone, Ciba-Geigy Ltd., Basle, Switzerland) every January and June.

Study Design and Data Collection

Goats were grouped into 3 age groups (>12 to ≤24, >24 to ≤36, and >36 months) for each breed and sex categories (Table 1). For Arsi-Bale breed, we included two age categories for young goats (≤6 months, n=4; >6 to ≤12 months, n=8), which were used for separate data analysis. Sampling was repeated 4 times a year (in the long rainy season, immediately following the long rainy season, in the dry season, and in the short rainy season) to see the effect of season. Data pertaining to the sampling date for hematological values was also recorded.

Since the handling of animals induces a change in blood parameters, blood was

drawn from the animals at rest, with minimum disturbance or excitement;[8] this was accomplished by allowing animals to rest at least 4 minutes of an adaptation time before sampling. Rectal temperature, pulse, and respiratory rates were also checked for apparent normality. The sampling time was adjusted for all goats at around 9:00 a.m. to avoid the effect of diurnal variation.

About 4 mL of jugular blood was drawn in a dry, clean, and heparinized vacutainer tube; and immediately tipped back and forth a dozen times to dissolve the anticoagulants. The mixing of blood was done gently to avoid rough handling and/or to avoid any undesirable rupture of erythrocytes.

Laboratory Analyses

Hematological values were determined according to the standard procedures.[3,8,9,10] Erythrocyte and total white blood cell (WBC) counts were performed by the improved Neubauer hematocytometer (Fisher Scientific, Loughborough, U.K.). Ganti's fluid, an ideal RBC dilution fluid was used for RBC count. Two percent glacial acetic acid was used as dilution fluid for total WBC counts. The hematocrit (packed cell volume [PCV]) value was determined by the microhematocrit method, centrifuging at 12,000 rpm for 10 minutes. Acid-hematin method was used to determine hemoglobin (Hb) concentration using Sahli-Helling's hemoglobinometer (Fisher Scientific, Loughborough, U.K.). Blood smears were stained with Giemsa's stain to calculate the differential leukocyte percentage, counting 200 leukocytes differentiating and expressing as a percentage.

Wintrobe indices (mean corpuscular volume [MCV], mean corpuscular hemoglobin [MCH] and mean corpuscular hemoglobin concentration [MCHC]) were calculated from values of RBC count, PCV percentages and Hb concentration by the conventional method.[3]

Statistical Analyses

The experimental design has been described earlier. The dependent variables analyzed were RBC, PCV, Hb, MCV, MCH, MCHC, WBC, Lymphocytes, Neutrophils, Monocytes, Eosinophils, and Basophils. Data were analyzed using the MIXED procedures of the Statistical Analysis Systems Institute.[11] Repeated measures refer to data sets with multiple measurements of a response variable on the same experimental unit. In this experiment, repeated measures were taken on individual animals every season (rainy, after rainy, dry and short-rainy seasons). PROC MIXED fits mixed (ie, fixed and random effects) linear models. The random variable fitted was the effect of experimental animals.

The effects of breed, sex, age, class, and their first order interactions were fitted for all independent variables. Interactions among the main effects were retained in the final models whether found significant ($P<0.05$) or not in preliminary analyses. Measurement dates were used as a within-subjects factor for repeated measures taken on individual animals, and their interactions with main effects were also fitted in all the models. The 'season' fitted in the models; mean measurement dates could indicate different intervals between measurement dates. Since within-breed means by sex and age classes were deemed important for reference, separate data analyses was done for each breed and reported accordingly.

When analyzing repeated measures data, the REPEATED statement is normally used to model the covariance structure within subjects. PROC MIXED provides a number of covariance types from which to select. The covariance structure selected in these analyses was "unstructured". That is, no mathematical pattern is imposed on the covariance matrix. The decision process in choosing the covariance structure can be assisted by using two model-fit criteria computed by PROC MIXED, Akaike's Information Criterion (AIC) and Schwarz' Bayesian Criterion (SBC). These are essentially log-likelihood values penalized for the number of parameters estimated.[11] The covariance structure with values of the criteria closest to zero is

Table 2. Least Squares Means (and standard errors) of Erythrocytic Series in Three Goat Breeds/Types*

Source of variation	RBC (10^6)	PCV (%)	Hb (g dL^{-1})	MCV (fL)	MCH (pg)	MCHC (g dL^{-1})
Overall	12.93±0.18	25.23±0.22	10.69±0.11	20.45±0.35	8.53±0.11	42.94±0.30
C.V. (%)	20.68	11.76	14.40	20.53	21.05	11.66
Breed	NS	‖	‖	‖	‖	‖
Arsi-Bale	12.57±0.26	25.53±0.36[a]	11.25±0.16[a]	21.10±0.43[a]	9.25±0.17[a]	44.66±0.45[a]
Central highland	13.06±0.25	26.28±0.35[a]	10.29±0.16[b]	21.15±0.43[a]	8.19±0.16[b]	39.68±0.41[b]
Long-eared Somali	13.15±0.27	23.89±0.37[b]	10.52±0.17[b]	19.10±0.44[b]	8.34±0.17[b]	44.49±0.45[a]
Sex	‡	†	NS	NS	†	NS
Female	13.38±0.20	25.65±0.26	10.84±0.12	20.13±0.37	8.42±0.13	42.58±0.34
Male	12.48±0.25	24.81±0.34	10.53±0.16	20.78±0.42	8.77±0.16	43.30±0.42
Age group (months)	NS	NS	NS	NS	NS	NS
>12–≤24	12.98±0.24	24.83±0.32	10.62±0.16	20.08±0.41	8.50±0.16	43.23±0.45
>24–≤36	12.65±0.31	25.68±0.40	10.74±0.19	21.16±0.49	8.80±0.19	42.42±0.49
>36	13.16±0.22	25.18±0.29	10.69±0.13	20.11±0.39	8.48±0.14	43.17±0.37
Season	‖	‖	‖	‖	‡	‖
Rainy	10.47±0.43[c]	23.04±0.46[b]	9.68±0.27[c]	23.62±1.13[a]	9.50±0.30[a]	43.38±0.97[a]
After rainy	13.92±0.32[a]	25.78±0.29[a]	10.64±0.15[b]	19.59±0.47[b]	8.20±0.22[b]	41.56±0.48[b]
Dry	13.25±0.18[b]	25.91±0.25[a]	10.93±0.12[b]	19.80±0.25[b]	8.37±0.12[b]	42.51±0.41[b]
Short rainy	14.07±0.17[a]	26.18±0.23[a]	11.49±0.10[a]	18.79±0.22[c]	8.31±0.11[b]	44.32±0.31[a]
Breed × Sex	‖	NS	†	†	‡	NS
Breed × Age group	§	‡	NS	NS	NS	NS
Sex × Age group	§	NS	NS	‡	‡	NS

*NS, indicates not significant ($P>0.05$); fL, femto liter; g dL^{-1}, gram per deciliter; Hb, hemoglobin; MCV, mean corpuscular volume MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; PCV, packed cell volume; and RBC, red blood cells.
†$P<0.05$; ‡$P<0.01$; §$P<0.001$; ‖$P<0.0001$. [a,b,c]Means with different letters within a trait in a column are different at indicated P value.

considered most desirable. Thus, based on this condition "unstructured" covariance was selected. The Tukey-Kramer test was used to separate means of effects with 3 or more levels which were significant in the least squares analyses of variance.

RESULTS

The least squares means (and standard errors) of erythrocytic series are presented in Table 2. The overall estimates (ie, across factors) for RBC, PCV, Hb, MCV, MCH, and MCHC were 12.93±0.18 million μL^{-1}, 25.23±0.22%, 10.69±0.11 g dL^{-1}, 20.45±0.35 fL, 8.53±0.11 pg and 42.94±0.30 g dL^{-1}, respectively.

Least squares means of leukocytic series are presented in Table 3. Overall estimates were as follows: WBC, 11.32±0.27 thousand μL^{-1}; lymphocytes, 61.69±0.59%; neutrophils, 33.99±0.59%; eosinophils, 2.69±0.18%; monocytes, 1.98±0.11%; and basophils, 0.22±0.03%.

Effect of Breed

There were significant ($P<0.0001$) breed differences for PCV, Hb, MCV, MCH, and MCHC (Table 2). The LES goats had significantly lower ($P<0.0001$) PCV and MCV compared to other breeds while AB goats had higher ($P<0.0001$) Hb concentration. MCH and MCHC for the CH goats were significantly low ($P<0.0001$) owing to low Hb value recorded for the breed.

Table 3. Least Squares Means (and Standard Errors) of Leukocytic Series in Three Goat Breeds/Types*

Source of variation	WBC (10^3)	Lymphocytes (%)	Neutrophils (%)	Eosinophils (%)	Monocytes (%)	Basophils (%)
Overall	11.32±0.27	61.69±0.59	33.99±0.59	2.69±0.18	1.98±0.11	0.22±0.03
CV (%)	30.39	17.79	31.84	60.41	89.97	327.36
Breed	†	‖	‖	NS	NS	‖
Arsi–Bale	10.70±0.37[b]	63.12±0.94[a]	32.39±0.93[b]	3.00±0.22	1.61±0.08	0.01±0.02[b]
Central highland	12.07±0.38[a]	49.76±1.10[b]	46.23±1.07[a]	3.37±0.27	1.98±0.19	0.62±0.05[a]
Long–eared Somali	11.19±0.37[b]	65.26±0.97[a]	30.13±0.95[b]	3.07±0.23	1.62±0.08	0.01±0.02[b]
Sex	‡	‖	‖	†	NS	NS
Female	11.95±0.29	62.82±0.74	32.08±0.72	3.52±0.19	1.85±0.09	0.24±0.02
Male	10.69±0.36	55.95±0.99	40.42±0.95	2.78±0.22	1.62±0.11	0.18±0.03
Age group (months)	‖	‖	‖	‖	NS	NS
>12–≤24	13.52±0.36[a]	64.43±0.99[a]	31.88±1.00[b]	2.70±0.28[b]	1.66±0.12	0.24±0.03
>24–≤36	10.17±0.43[b]	57.25±1.32[b]	38.55±1.27[a]	3.21±0.28[a]	1.70±0.15	0.18±0.04
>36	10.27±0.33[b]	56.47±0.76[b]	38.32±0.73[a]	3.53±0.17[a]	1.85±0.09	0.22±0.02
Season	‡	‡	NS	‡	‖	†
Rainy	12.02±0.72[a]	NA	NA	NA	0.10±0.09[c]	0.20±0.02[b]
After rainy	12.04±0.36[a]	57.78±1.23[b]	37.19±1.14	3.70±0.34[a]	2.70±0.24[a]	0.22±0.03[b]
Dry	10.60±0.25[b]	59.22±0.69[b]	36.18±0.73	2.95±0.18[b]	2.45±0.14[a]	0.13±0.04[c]
Short rainy	10.61±0.23[b]	61.15±0.73[a]	35.38±0.69	2.79±0.20[b]	1.69±0.11[b]	0.30±0.04 [a]
Breed × Sex	†	NS	†	†	‡	NS
Breed × Age group	§	‡	NS	NS	NS	NS
Sex × Age group	NS	NS	NS	‡	‡	NS

*NS, indicates not significant ($P>0.05$); WBC, White blood cells; and NA, data not available.
†$P<0.05$; ‡$P<0.01$; §$P<0.001$; ‖$P<0.0001$. [a,b,c]Means with different letters within a trait in a column are different at indicated P value.

Both total and differential leukocyte counts revealed significant breed differences for WBC, lymphocytes, neutrophils, and basophils (Table 3). CH goats had significantly higher ($P<0.05$) WBC than the other two breeds. Lymphocytes were significantly lower ($P<0.0001$) in CH than in AB and LES goats. Neutrophils ($P<0.0001$) and basophils ($P<0.001$) were significantly higher in CH than in AB and LES goats.

Effect of Sex

There were significant sex difference (at least $P<0.05$) for RBC, PCV, and MCH parameters (Table 2). The values of RBC ($P<0.01$) and PCV ($P<0.05$) were significantly higher in females than males while the reverse was true for MCH ($P<0.05$). Leukocyte counts also revealed significant sex differences. WBC ($P<0.01$), lymphocytes ($P<0.0001$) and eosinophils ($P<0.05$) were significantly higher in females than in males (Table 3). Conversely, neutrophils were significantly higher in males than in females ($P<0.0001$).

Effect of Age

There was no significant age difference in all erythrocytic series ($P>0.05$, Table 2). However, all leukocytic series except monocytes and basophils were significantly affected by age ($P<0.0001$, Table 3). WBC and lymphocytes were higher in goats older than 12 and younger than 24 months, than in older age categories. Conversely, neutrophils and eosinophils were higher

Table 4. Least Squares Means (and Standard Errors) of Erythrocytic Series in Arsi-Bale Goats*

Source of variation	RBC (10^6)	PCV (%)	Hb (g dL^{-1})	MCV (fL)	MCH (pg)	MCHC (g dL^{-1})
Overall	13.94±0.30	26.45±0.36	11.50±0.15	19.51±0.42	8.51±0.18	44.65±0.33
C.V. (%)	24.06	11.81	13.41	20.65	23.46	8.31
Sex	§	†	†	†	‡	NS
Female	15.00±0.36	27.32±0.44	11.88±0.19	18.69±0.48	8.04±0.21	44.35±0.39
Male	12.89±0.39	25.58±0.48	11.12±0.21	20.33±0.52	8.97±0.23	44.95±0.42
Age group (months)	NS	NS	NS	NS	†	NS
≤ 6	15.10±1.12	27.37±1.17	10.88±0.48	17.30±1.72	6.37±0.72 [b]	44.14±1.27
>6–≤ 12	14.03±0.48	26.05±0.55	11.75±0.27	19.72±0.62	8.78±0.30 [a]	45.56±0.55
>12–≤24	13.96±0.54	25.91±0.67	11.60±0.32	19.81±0.68	8.92±0.32 [a]	44.58±0.65
>24–≤36	13.61±0.57	26.29±0.75	11.54±0.33	20.04±0.70	9.01±0.33 [a]	44.05±0.60
>36	13.03±0.36	26.61±0.45	11.75±0.20	20.69±0.44	9.45±0.20 [a]	44.93±0.36
Season	NS	NS	†	‡	†	§
Rainy	NA	NA	NA	NA	NA	NA
After rainy	13.38±0.49	26.35±0.46	11.27±0.21 [b]	21.26±0.66 [a]	9.28±0.31 [a]	43.90±0.50 [b]
Dry	14.17±0.42	26.58±0.44	11.38±0.21 [b]	19.01±0.54 [b]	8.01±0.25 [b]	43.82±0.59 [b]
Short rainy	14.28±0.35	26.42±0.43	11.85±0.19 [a]	18.26±0.48 [b]	8.23±0.22 [b]	46.23±0.44 [a]

*NS indicates not significant ($P>0.05$); NA, data not available; fL, femto liter; g dL^{-1}, gram per deciliter; Hb, hemoglobin; MCV, mean corpuscular volume MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; PCV, packed cell volume; and RBC, red blood cells.
†$P<0.01$; ‡$P<0.001$; §$P<0.0001$. [a,b]Means with different letters within a trait in a column are different at indicated P value.

($P<0.0001$) in the other two older age categories.

Effect of Season

There was significant (at least $P<0.01$) seasonal variation for all erythrocytic series (Table 2). RBC was higher ($P<0.0001$) during the after rainy and short rainy seasons. PCV and Hb were significantly lower ($P<0.0001$) during the long rainy season than any other season. All of the Wintrobe indices (MCV, MCH, and MCHC) were higher during the long rainy season except that MCHC was also high during the short rainy season.

Leukocyte counts also revealed seasonal variation (at least $P<0.05$) (Table 2). WBC was significantly higher ($P<0.01$) in the long rainy and after rainy seasons than in any other seasons. Lymphocytes were significantly higher ($P<0.01$) in the short rainy season than in after rainy and dry seasons. Eosinophils were significantly higher ($P<0.01$) in after rainy season than in dry and short rainy seasons while monocytes were higher ($P<0.0001$) both in dry and after rainy seasons than any other seasons. Basophils were higher ($P<0.05$) in short rainy seasons than in any other seasons.

Interactions

There were significant breed by sex, breed by age, and sex by age interactions for most of the erythrocytic and leukocytic series (Tables 2 and 3). However, most of them had limited biological significance, although some of them require further mention. For example, CH males had significantly higher ($P<0.001$) RBC than AB males. Males of LES had significantly higher ($P<0.05$) RBC than males of AB goats. On the other hand, AB females had significantly higher RBC ($P<0.05$) and Hb ($P<0.001$) than CH and LES females.

Results of Separate Analyses by Breed

In the AB breed (Tables 4 and 5), females had significantly higher (at least $P<0.01$)

Table 5. Least Squares Means (and Standard Errors) of Leukocytic Series in Arsi-Bale Goats*

Source of variation	WBC (10^3)	Lymphocytes (%)	Neutrophils (%)	Eosinophils (%)	Monocytes (%)	Basophils (%)
Overall	11.88±0.30	65.62±0.76	30.04±0.74	2.63±0.20	1.91±0.11	0.002±0.010
C.V. (%)	33.94	13.85	27.86	62.44	88.39	1509.97
Sex	‡	‖	‖	§	NS	NS
Female	12.68±0.36	68.77±0.95	26.20±0.93	3.21±0.23	1.94±0.12	0.002±0.01
Male	11.08±0.41	62.46±1.04	33.89±1.02	2.06±0.25	1.87±0.13	0.000±0.010
Age group (months)	‖	‖	§	§	†	NS
≤ 6	13.36±1.18[a]	68.30±2.43[a]	27.97±2.34[b]	1.55±0.76[b]	2.50±0.44[a]	0.019±0.050
>6 – ≤ 12	14.29±0.49[a]	68.63±1.25[a]	26.80±1.22[b]	2.51±0.38[b]	2.44±0.27[a]	0.007±0.007
>12 – ≤24	12.58±0.55[a]	69.14±1.44[a]	28.14±1.42[b]	2.22±0.42[b]	1.32±0.15[b]	0.006±0.006
>24 – ≤36	9.43±0.58[b]	61.38±1.61[b]	33.71±1.59[a]	3.10±0.33[a]	1.56±0.17[b]	0.009±0.007
>36	9.74±0.38[b]	60.63±0.97[b]	33.60±0.95[a]	3.80±0.20[a]	1.72±0.11[b]	0.006±0.006
Season	‡	‡	NS	NS	‖	NS
Rainy	NA	NA	NA	NA	0.36±0.15[b]	0.004±0.010
After rainy	12.82±0.53[a]	63.70±1.08[b]	31.30±1.04	3.23±0.29	2.54±0.19[a]	0.021±0.021
Dry	11.86±0.47[a]	65.34±0.96[b]	30.32±0.96	2.38±0.28	2.75±0.25[a]	0.005±0.011
Short rainy	10.96±0.38[b]	67.81±0.98[a]	28.51±0.96	2.29±0.32	1.97±0.22[a]	0.005±0.012

*NS, not significant (P>0.05); WBC, white blood cells; and NA, data not available.
†P<0.05; ‡P<0.01; §P<0.001; ‖P<0.0001. [a,b]Means with different letters within a trait in a column are different at indicated P value.

RBC, PCV, and Hb than males. However, the converse was true with MCV and MCH (at least P<0.01). Season was also an important factor affecting most of the erythrocytic series. Generally, in this breed, WBC and lymphocytes decreased with increasing age, while the converse was true for neutrophils and eosinophils. Females had significantly (at least P<0.01) higher WBC, lymphocytes, and eosinophils than males, while the converse was true in case of neutrophils.

In CH goats, females had significantly lower RBC (P<0.05) than males (Tables 6 and 7). Animals in age group between 12 and 24 months had significantly higher PCV (P<0.05) than older age groups. Season affected almost all erythrocytic series in CH goats. RBC and PCV were significantly lower during short rainy season than any other season, but the reverse was true for MCV and MCH. WBC and lymphocytes were significantly (at least P<0.05) higher in females than males while the reverse was true in case of neutrophils. Lymphocytes significantly decreased as age increased while the reverse was true for neutrophils. WBC was significantly (P<0.05) higher during long rainy and immediately after rainy seasons.

In LES goats (Tables 8 and 9), females had significantly (P<0.05) higher RBC than males. Animals in the older age group had significantly (at least P<0.05) higher RBC, PCV, and MCH than animals in younger age groups. Although there was no clear pattern, season significantly (at least P<0.05) affected all erythrocytic parameters. WBC, lymphocytes, and eosinophils were significantly (at least P<0.01) higher in females than males, while the reverse was true in case of neutrophils. Both WBC and lymphocytes decreased with increasing age while the converse was true with neutrophils.

DISCUSSION

This study of hematological parameters of indigenous goats is the first report from Ethiopia. Related studies were carried out on indigenous sheep breeds.[12]

In general, the hematological profiles of the indigenous goat breeds of Ethiopia compare favorably, and were within the range

Table 6. Least Squares Means (and Standard Errors) of Erythrocytic Series in Central Highland Goats*

Source of variation	RBC (10^6)	PCV (%)	Hb (g dL^{-1})	MCV (fL)	MCH (pg)	MCHC (g dL^{-1})
Overall	13.22±0.23	26.46±0.35	10.30±0.15	20.63±0.43	8.06±0.15	39.63±0.44
C.V. (%)	19.61	12.18	14.59	21.26	19.17	12.72
Sex	†	NS	NS	NS	NS	NS
Female	12.75±0.27	26.32±0.43	10.18±0.18	21.18±0.48	8.20±0.18	39.07±0.55
Male	13.69±0.34	26.60±0.56	10.42±0.23	20.08±0.57	7.91±0.22	40.18±0.70
Age group (months)	NS	†	NS	NS	NS	NS
>12–≤24	13.69±0.33	27.02±0.47[a]	10.60±0.22	20.57±0.55	8.04±0.21	39.35±0.72
>24–≤36	13.31±0.37	26.81±0.47[a]	10.16±0.24	20.86±0.63	7.92±0.23	39.10±0.79
>36	12.65±0.31	25.55±0.48[b]	10.14±0.21	20.45±0.55	8.21±0.20	40.43±0.63
Season	§	‖	‖	‡	§	NS
Rainy	10.75±0.44[b]	24.51±0.49[b]	9.28±0.27[c]	23.25±1.11[a]	9.00±0.30[a]	39.73±0.96
After rainy	13.97±0.38[a]	26.97±0.52[a]	10.37±0.25[b]	20.07±0.91[ab]	7.65±0.32[b]	38.76±0.81
Dry	14.03±0.26[a]	26.66±0.46[a]	10.37±0.19[b]	19.23±0.37[c]	7.51±0.16[b]	39.28±0.85
Short rainy	14.11±0.30[a]	27.70±0.45[a]	11.18±0.18[a]	19.97±0.43[b]	8.06±0.19[b]	40.74±0.74

*NS indicates not significant ($P>0.05$); fL, femto liter; g dL^{-1}, gram per deciliter; Hb, hemoglobin; MCV, mean corpuscular volume MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; PCV, packed cell volume; and RBC, red blood cells.
†$P<0.05$; ‡$P<0.01$; §$P<0.001$; ‖$P<0.0001$. [a,b,c]Means with different letters within a trait in a column are different at indicated P value.

Table 7. Least Squares Means (and Standard Errors) of Leukocytic Series in Central Highland Goats*

Source of variation	WBC (10^3)	Lymphocytes (%)	Neutrophils (%)	Eosinophils (%)	Monocytes (%)	Basophils (%)
Overall	12.05±0.37	50.70±1.14	44.97±1.32	3.10±0.20	2.29±0.12	0.65±0.09
C.V. (%)	26.85	17.80	23.21	51.02	44.47	124.24
Sex	NS	†	‡	NS	NS	NS
Female	11.99±0.42	53.60±1.44	40.85±1.70	3.15±0.27	2.46±0.15	0.74±0.12
Male	12.11±0.52	47.81±1.81	49.10±2.02	3.05±0.30	2.13±0.18	0.56±0.14
Age group (months)	NS	‡	†	NS	NS	NS
>12 – ≤24	12.81±0.51	54.91±2.00[a]	40.10±2.35[b]	3.03±0.34	2.30±0.21	0.73±0.16
>24 – ≤36	11.97±0.56	50.85±2.39[b]	46.29±2.70[a]	3.09±0.45	2.16±0.24	0.55±0.19
>36	11.37±0.48	46.35±1.53[b]	48.53±1.76[a]	3.18±0.27	2.42±0.16	0.66±0.12
Season	†	NS	†	NS	NS	‡
Rainy	12.69±0.74[a]	NA	NA	NA	NA	NA
After rainy	12.72±0.56[a]	NA	NA	NA	NA	NA
Dry	10.99±0.39[b]	52.33±1.40	43.08±1.64	3.03±0.27	2.50±0.18	0.38±0.12
Short rainy	11.81±0.37[a]	49.08±1.42	46.87±1.47	3.17±0.30	2.08±0.15	0.92±0.14

*NS, indicates not significant ($P>0.05$); WBC, White blood cells; and NA, data not available.
†$P<0.05$; ‡$P<0.01$. [a,b]Means with different letters within a trait in a column are different at indicated P value.

for caprine species.[3,8,10] However, when genuine comparisons are made, important breed differences were observed in a number of the parameters (Table 10). The values for RBC in the 3 studied breeds are slightly higher than the mean value reported for Tswana goats.[13] However, PCV values in indigenous goats were lower than the report-

Table 8. Least Squares Means (and Standard Errors) of Erythrocytic Series in Long-Eared Somali Goats

Source of variation	RBC (10^6)	PCV (%)	Hb (g dL^{-1})	MCV (fL)	MCH (pg)	MCHC (g dL^{-1})
Overall	14.07±0.31	24.67±0.33	10.87±0.16	17.84±0.38	7.90±0.18	44.04±0.38
C.V. (%)	17.84	10.19	11.96	17.21	18.59	9.33
Sex	†	NS	NS	NS	NS	NS
Female	14.58±0.36	25.05±0.40	10.89±0.19	17.66±0.45	7.83±0.21	44.01±0.45
Male	13.56±0.43	24.29±0.51	10.86±0.23	18.02±0.55	7.98±0.25	44.06±0.56
Age group (months)	§	‡	†	NS	‡	NS
>12 - ≤24	13.07±0.42[b]	23.10±0.54[b]	10.28±0.27[b]	18.13±0.57	8.15±0.27[a]	44.63±0.67
>24 - ≤36	13.79±0.56[b]	25.83±0.67[a]	11.47±0.29[a]	18.63±0.73	8.30±0.33[a]	44.07±0.68
>36	15.35±0.41[a]	25.07±0.45[a]	10.86±0.20[b]	16.75±0.50	7.26±0.23[b]	43.41±0.47
Season	§	NS	§	§	‡	‖
Rainy	NA	NA	NA	NA	NA	NA
After rainy	14.31±0.57[a]	24.50±0.42	10.26±0.27[b]	17.69±0.57[b]	7.50±0.33[b]	41.57±0.92[b]
Dry	13.20±0.32[b]	24.94±0.40	10.98±0.21[b]	18.97±0.50[a]	8.39±0.20[a]	44.24±0.61[b]
Short rainy	14.70±0.29[a]	24.56±0.35	11.38±0.15[a]	16.85±0.35[b]	7.81±0.17[b]	46.30±0.39[a]

*NS indicates not significant (P>0.05); NA, data not available; fL, femto liter; g dL^{-1}, gram per deciliter; Hb, hemoglobin; MCV, mean corpuscular volume MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; PCV, packed cell volume; and RBC, red blood cells.
†P<0.05; ‡P<0.01; §P<0.001; ‖P<0.0001. [a,b]Means with different letters within a trait in a column are different at indicated P value.

Table 9. Least Squares Means (and Standard Errors) of Leukocytic Series in Long-Eared Somali Goats

Source of variation	WBC (10^3)	Lymphocytes (%)	Neutrophils (%)	Eosinophils (%)	Monocytes (%)	Basophils (%)
Overall	11.09±0.36	65.76±0.98	29.58±0.87	3.01±0.24	1.68±0.09	0.00
C.V. (%)	34.35	14.11	29.10	63.53	109.74	0.00
Sex	‡	§	‖	†	NS	
Female	12.20±0.44	68.99±1.15	25.95±1.03	3.49±0.30	1.74±0.09	0.00
Male	9.97±0.58	62.54±1.43	33.21±1.29	2.53±0.35	1.62±0.10	0.00
Age group (months)	‖	§	‡	NS	NS	
>12 – ≤24	14.95±0.70[a]	70.79±1.57[a]	25.82±1.47[b]	2.69±0.55	1.62±0.11	0.00
>24 – ≤36	9.02±0.69[b]	63.51±1.84[b]	31.19±1.64[a]	2.90±0.39	1.68±0.11	0.00
>36	9.29±0.50[b]	62.99±1.26[b]	31.73±1.12[a]	3.43±0.29	1.74±0.09	0.00
Season	†	‡	NS	NS	§	
Rainy	NA	NA	NA	NA	0.02±0.05[c]	NA
After rainy	12.30±0.63[a]	64.51±1.93[b]	29.77±1.75	3.40±0.43	2.66±0.33[a]	0.00
Dry	10.78±0.46[b]	63.94±1.08[b]	30.94±1.09	3.01±0.36	2.68±0.29[a]	0.00
Short rainy	10.18±0.47[b]	68.84±1.17[a]	28.02±1.07	2.60±0.41	1.39±0.17[b]	0.00

*NS indicates not significant (P>0.05); WBC, white blood cells; and NA, data not available.
†P<0.05; ‡P<0.01; §P<0.001; ‖P<0.0001. [a,b]Means with different letters within a trait in a column are different at indicated P value.

ed averages in many of the goat breeds.[13,14,15] The Hb concentration of the indigenous breeds was slightly higher than the mean values reported for other tropical goats.[3,15,16] Nonetheless, higher Hb value was reported for Tswana goats.[13] The effect of altitude on erythrocytic values has been studied by many investigators and it is now a well established fact that reduced oxygen tension, in mountainous regions, leads to an increased production and release of erythropoietin, thereby, stimulating erythropoiesis as a coping or adaptive mechanism to low oxygen level in such an environment.[3,8,10]

Therefore, the higher RBC and Hb values exhibited in indigenous breeds in this study under high altitudes (1650 m and 2800 m above sea level) could provide evidence of the adaptation of these breeds to low atmospheric oxygen. On the other extreme, it is also important to note that some indigenous goats had a minimum PCV value of 16.5% (data not presented) without any clinical manifestation of anemia, the value lower than the lower limit reported for the species.[8,10,13,15] The differences between breeds observed in the average Wintrobe indices could be associated with factors that influenced RBC, Hb, and PCV.

The mean total WBC values observed in this study were in close agreement with a report for Black Bengal goats[14] but were higher than the findings for temperate goat breeds,[3,8] for tropical goats[16] at 8.0±0.6 x 10^3 μL^{-1}, for Sokoto Red, Kano Brown, Salla and Borono White goats in Nigeria.[17] The values were lower than the mean values for Galla goats[10,15] at 15.4±0.20 x 10^3 μL^{-1} in Kenya, for West African Dwarf goats[17] at 13.5±6.37 x 10^3 μL^{-1} and for Tswana goats [13] at 13.3±1.7 x 10^3 μL^{-1}.

The significant breed differences found for lymphocytes, neutrophils, and basophils are suggestive of the existence of breed variation. Breed difference for these parameters were also reported earlier.[3] The lymphocytes recorded in this study were higher than the mean values reported by many authors for the species.[3,8,10] However, it falls within the range reported for Galla goats in Kenya.[16] Other leucocytes compares favorably with earlier reports for the species with slight breed differences.[3,8,10]

The higher RBC, PCV, WBC, lymphocytes, neutrophils, and eosinophils observed in females than males might be attributed to various physiological factors associated with females. For example, during estrous females are in a restless and excited condition, where splenic contraction may increase the erythrocyte values.[3,10] A similar observation was made in indigenous sheep breeds by Tibbo et al (unpublished data). A slight

Table 10. Hematological Parameters of Some Goat Breeds Obtained from the Literature*

Parameter	Arsi-Bale†	Central Highland†	Long-eared Somali†	Black Bengal[14]	Galla[15]	Red-Sokoto[16]	Red-Sokoto[17]	WAD[16]	WAD[17]	Tswana[13]
RBC (10^6 μL^{-1})	13.94	13.22	14.07	10.88	18.88	13.8	8.17	13.60	7.09	12.68
PCV (%)	26.45	26.46	24.67	30.16	30.45	27.50	28.14	24.80	23.67	32.00
Hb (g dL^{-1})	11.50	10.30	10.87	12.10	10.08	9.20	9.95	9.80	7.73	12.10
MCV (fL)	19.51	20.63	17.84	NA	36.79	19.90	35.77	18.20	34.33	25.71
MCH (pg)	8.51	8.06	7.90	NA	5.52	6.00	11.75	7.20	11.00	9.51
MCHC (g dL^{-1})	44.65	39.63	44.04	NA	34.27	33.4	32.26	39.60	32.67	36.70
WBC (10^3 μL^{-1})	11.88	12.05	11.09	12.40	15.38	7.50	9.21	7.50	13.48	NA
Lymphocytes (%)	65.62	50.70	65.76	51.59	62.01	57.30	50.01	53.30	53.00	56.00
Neutrophils (%)	30.04	44.97	29.58	35.62	35.71	34.80	48.01	36.50	46.17	36.00
Eosinophils (%)	2.63	3.10	3.01	2.91	1.43	5.80	1.10	6.30	NA	5.00
Monocytes (%)	1.91	2.29	1.68	8.01	1.35	3.00	1.30	3.80	1.25	2.50
Basophils (%)	Nil	0.65	Nil	1.87	Nil	0.70	NA	0.50	NA	0.50

*NA, data not available. †Goat breeds of the present study.

increase in erythrocyte values in adult female goats than males was reported citing the work of Wilkins and Hodges (1962).[3] Different from our findings, slightly higher PCV, RBC, and Hb values in males than in females were reported.[5,10,17] An increase in leukocytic series in females might also be associated with estrus. An increase in neutrophils during estrus was observed in Blackhead Ogaden sheep with an effect on the total WBC in females.[12]

There was no significant age effect in most of the erythrocytic series, although there was a decreasing trend in RBC and an increasing trend in both Hb and MCH in AB goats as age increased (Table 4). In this breed, lower MCH was observed in kids less than 6 months of age, owing to the relatively higher RBC recorded in this age group, which means that the smaller the cell size, the higher the RBC and the lower the MCV and MCH values will be. The higher lymphocyte percentage recorded in animals younger than 2 years, compared to old age groups, might reflect the development of active immunity and explain why total WBC observed in these age groups was higher. Age-related hematological changes were also reported earlier by many investigators.[3,5,8,10,12,18,19]

The fact that the RBC, PCV, and Hb values are lower in the rainy season than any other season might be associated with increased parasite challenge and/or increased water intake through the lush grasses that are available for grazing in that season. Similarly, higher RBC, Hb, and PCV have been recorded in late summer and autumn than in winter and spring, in various animal species.[5,8,13] The highest erythrocytic values in the short rainy season might suggest a minimum parasite challenge and better nutritional status of animal in this season. The same factors might have influenced the Wintrobe indices. The higher total WBC recorded during the long rainy and after rainy seasons might be due to the high challenges from the cool temperature and wet environment of the season, predisposing animals to infections. In general, the seasonal variation observed in these parameters might partly be associated with nutritional availability, environmental, and other management factors that vary with the seasons.

This study revealed the influences of breed, sex, age, and season on the hematological values. The RBC, Hb, lymphocytes, and neutrophils of the indigenous goat breeds were remarkably different from most other exotic goat breeds. These differences could complicate the interpretation of hematological findings on sick indigenous goats, if not taken into account. Hence, the blood values from this study could be used as reference to assess the health status of the 3 goat indigenous breeds in Ethiopia.

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REFERENCES

1. CSA (Central Statistics Authority). *The 2001/2002 Ethiopian Agricultural Sample Enumeration, Executive Summary, May 2004*. Addis Ababa, Ethiopia: Central Statistics Authority; 2004.
2. Ademosum AA. Constraints and Prospects for Small Ruminant Research and Development in Africa. In: Lebbie SHB, Rey B, Irungu B, eds. *Proceedings of the Second Biennial Conference of the African Small Ruminants Research Network* held from 7-11 December 1992 in Arusha International Conference Center (AICC), Arusha, Tanzania: International Livestock Center for Africa (ILCA), Addis Ababa, Ethiopia; 1994:1–9.
3. Schalm OW, Jain NC, Carroll EJ. *Veterinary Hematology.* 3rd ed. Philadelphia, Pa: Lea & Febiger; 1975.
4. Dacie JV. *Practical Hematology*. 7th ed. London, England: Churchill Livingstone; 1991:556.
5. Sherman DM, Mary CS. Blood, lymph and immune systems. In: *Goat Medicine*. Philadelphia: Lea and Febiger; 1994.
6. FARM-Africa. *Goat types of Ethiopia and Eritrea. Physical description and management systems.* London, England, and Nairobi, Kenya: FARM-Africa and ILRI; 1996:76.

7. Tembely S, Lahlou-Kassi A, Rege JEO, Sovani S, Diedhiou ML, Baker RL. The epidemiology of nematode infections in sheep in a cool tropical environment. *Vet Parasitol.* 1997;70:129–141.

8. Jain NC. *Essentials of Veterinary Hematology.* Philadelphia, Pa: Lea and Febiger; 1993:417.

9. Sastry GA. *Veterinary Clinical Pathology*. 4th ed. New Delhi, India: CBS; 1985:1–32.

10. Coles EH. *Veterinary Clinical Pathology*. 4th ed. Philadelphia: W.B. Saunders Company; 1986:10–70.

11. SAS Institute Inc. *SAS/STAT Procedures Guide for Personal Computers.* Version 8 ed. Cary, NC: SAS Institute Inc; 1996.

12. Tafesse B. *A study on blood values of Black Head Ogaden sheep in Jijiga (Hararge)* [DVM thesis]. Debre Zeit, Ethiopia: Addis Ababa University; 1987.

13. Binta MG, Mushi EZ, Diteko T, Marobela B. Hematological profile of normal goats in Botswana. *Bull Anim Health Prod Afr.* 1996;44:185–186.

14. Dalapati MR, Bhowmik MK, Sarker S, Kasmal NK. Demodicosis of goats: hematological and biochemical changes. *Trop Anim Health Prod.* 1997;4:240–242.

15. Wesonga HO, Nandokha E. Normal hematological values of Galla goats in Kenya. *Bull Anim Health Prod Afr.* 1989;37:151–156.

16. Amakiri SF. Hematological studies of various indigenous and exotic breeds of goats and their F_1 crosses in Nigeria. *Bull Anim Health Prod Afr.* 1981;29:377–380.

17. Aba-Adulugba E, Joshua RA. Hematological studies in apparently normal five indigenous breeds of goats in Nigeria. *Bull Anim Health Prod Afr.* 1990;38:59–64.

18. Alonso AJ, Teresa RDE, Garcia M, Gonzalez JR, Vallejo M. The effects of age and reproductive status on serum and blood parameters in Merino breed sheep. *J Vet Med Assoc*. 1997;44:223–231.

19. Hawkey CM, Hart MG, Fitzgerald AK. Age-related hematological changes in captive Barbery sheep (*Ammotragus lervia*). *Res Vet Sci.* 1983;35:118–119.