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FACTORS AFFECTING THE HEMATOLOGICAL PARAMETERS IN DIFFERENT GOAT BREEDS FROM ITALY

Francesca Arfuso, Francesco Fazio, Maria Rizzo, Simona Marafioti, Elisa Zanghì, Giuseppe Piccione[1♦]

Department of Veterinary Sciences, Polo Universitario Annunziata, University of Messina, 98168, Messina, Italy
♦Corresponding author: giuseppe.piccione@unime.it

Abstract

Hematological parameters in healthy goats show several variations in relation to breed, age, reproductive status, environmental factors and management conditions. Therefore, there is the need to investigate these factors and how they affect the animal's hematology. The aims of this study were to establish hematological reference values of five Italian goat breeds at different age classes (1–2, 3–4 and over 5 years) considered in autumn and to evaluate the effects of some factors (breed, age and environmental conditions). Ninety-six dried female Aspromontana goats, 102 Girgentana goats, 99 Messinese goats, 96 Maltese goats and 108 Argentata dell'Etna goats, clinically healthy, were used. Blood samples were collected from each animal and analyzed for Red Blood Cell (RBC), White Blood Cell (WBC), Hemoglobin concentration (Hb), Hematocrit (Hct), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC) and Platelets (PLT). Statistical analysis showed the effect of breed ($P<0.05$) on all studied parameters and the effect of age ($P<0.05$) on: RBC and Hb in Messinese goats; Hct in Girgentana, Maltese and Argentata dell'Etna goats; MCV and MCHC in Argentata dell'Etna goats; WBC in Aspromontana goats; and PLT in Girgentana and Messinese goats. The findings of the present study may serve as reference values for hematology of Italian goat breeds studied in autumn which could help veterinarians to interpret laboratory data appropriately and to monitor animal health status in order to improve the management and conservation of these breeds.

Key words: goats, age, breed, hematological parameters, reference intervals

Hematological tests are important tools for evaluation of physiological and health status of farm animals and almost indispensable in organic farming, where permitted veterinary interventions are strictly regulated and limited in scope. Hematological analyses in farm animals have been extensively discussed as an essential part of clinical examination often pointing to a specific differential diagnosis or suggesting a prognosis (Braun et al., 2010; Polizopoulou, 2010).

Goat farming is an important reality on the Mediterranean livestock panorama. The raising of goats in Italy is primarily destined to the production of milk which can be directly consumed or transformed into cheeses. Considering the high economic values of goat among livestock farming systems, it is important to perform clinical and paraclinical exams in order to guarantee sanitary strategies control, prevention or treatment of diseases and to assure good management practices. It is well recognized that hematological parameters in healthy goats show several variations in relation to breed (Okonkwo et al., 2011; Zumbo et al., 2011), age (Piccione et al., 2010, 2014), reproductive status, housing, starvation, environmental factors, stress and transportation (Watson et al., 1994; Waziri et al., 2010). These differences have underscored the need to establish appropriate physiological baseline values for livestock which could be used in the realistic evaluation of the management practice, nutrition and diagnosis of health condition as well as in determining the physiological status of animals (Šimpragaa et al., 2013).

In this study, we focused on five Italian goat (*Capra hircus*) breeds selected for their high economic value: Aspromontana, Girgentana, Messinese, Maltese and Argentata dell'Etna. The animals were reared in Mediterranean areas characterized by a subtropical climate. Particularly, the average annual temperature is at least 18°C, the temperature of the coldest month is about 10°C, while the temperature of the warmest month exceeds 22°C. These goat breeds have inhabited these areas for several years and, for this reason, they developed good adaptation to the local Mediterranean weather showing high performance with remarkable ability for twin pregnancy and milk production despite the harsh environmental conditions.

The aim of this study was to obtain reference values for hematological parameters of female Aspromontana, Girgentana, Messinese, Maltese and Argentata dell'Etna goats, and to determine the differences existing among the breeds and the effect of age.

Material and methods

Animals

A total of 501 female non-pregnant and non-lactating goats were enrolled in the study in autumn (sunrise 6:31; sunset 19:00). The animals were reared in five different Italian farms, located between Sicily and Calabria regions. In particular, 96 Aspromontana goats (Group A) were obtained from Reggio Calabria, Calabria (Farm A); 102 Girgentana goats (Group B) from Agrigento, Sicily (Farm B); 99 Messinese goats (Group C) from Messina, Sicily (Farm C); 96 Maltese goats (Group D) from Siracusa, Sicily (Farm D); and 108 Argentata dell'Etna goats (Group E) from Catania, Sicily (Farm E). The farms' location and the respective climatic conditions recorded at sampling time are shown in Figure 1.

The temperature-humidity index (THI), an indicator of thermal comfort for goat, was calculated using the U.S. Weather Bureau's Temperature Humidity Index Formula for ruminant species (Potter and Jacobsen, 2000):

THI (°C) = T°ambient + (0.36 * point of steam condensation) + 41.5.

Environmental conditions of eco-geological area of goats' farms

Farms	Ambient Temperature (°C)			Relative Humidity (%)			Rainfall (mm)		
	Min	*Max*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*	*Mean*
A	11.2	22.4	18.3	64	72	68.0	8	64	36.2
B	10.0	22.7	17.8	62	72	67.0	7	60	30.0
C	10.5	22.2	18.0	63	70	66.5	6	63	36.1
D	10.7	22.6	17.0	62	72	68.7	6	60	30.0
E	11.0	23.0	17.8	63	75	69.0	9	65	37.0

Eco-geological area of goats' farms

Farms	*Latitude*	*Longitude*	*Altitude (m above sea levels)*
A	38°4'0"N	16°4'0"E	300
B	37°09'42.4"N	13°56'05.9"E	200
C	38°8'37''68 N	15°16'59''16 E	250
D	37°10'50"52 N	15°7'34"68 E	310
E	37°35'47.1"N	15°07'04.7"E	250

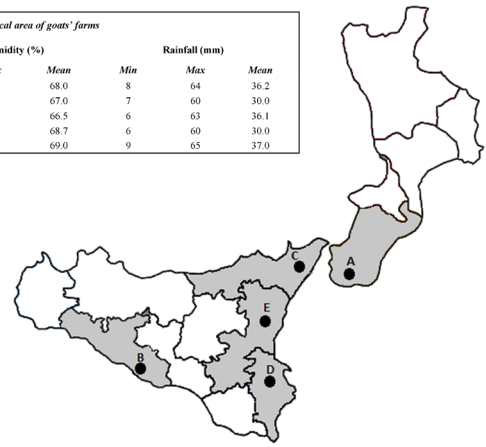


Figure 1. Geographical area of goats' farms with the respective environmental conditions

The temperature-humidity index (THI) values calculated for each farm are reported in Figure 2.

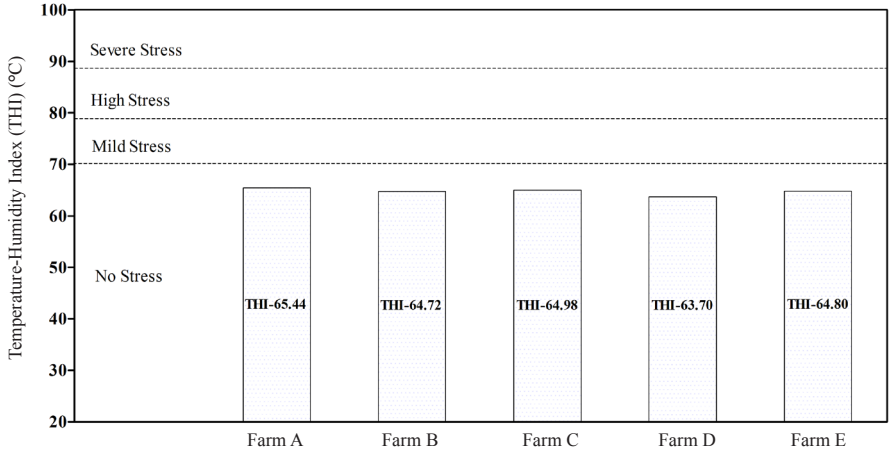


Figure 2. Temperature-humidity index (THI) values calculated for each farm

The animals, ranging from 1 to 10 years (Figure 3), were divided into three subgroups according to their age class (Table 1): I (1–2 years), II (3–4 years) and III (>5 years). Age was determined by tooth replacement and horn segment counts. All the animals enrolled in the study were defined clinically healthy with no evidence of disease and free from internal and external parasites. Their health status was evaluated based on rectal temperature, heart rate, respiratory profile, appetite, fecal consist-

ency and hematologic profile. Fresh fecal samples were examined with McMaster method based on protocols previously described by MAFF (1989). All the animals were kept under natural photoperiod and ambient temperature and were fed with the same constant diet composed of good-quality alfalfa hay and a concentrate mixture which consisted of the following ingredients: oats 23%, corn 36%, barley 38%, and minerals and supplements 3%. About 200 g/animal of concentrate was distributed once daily, whereas hay and water were available *ad libitum*.

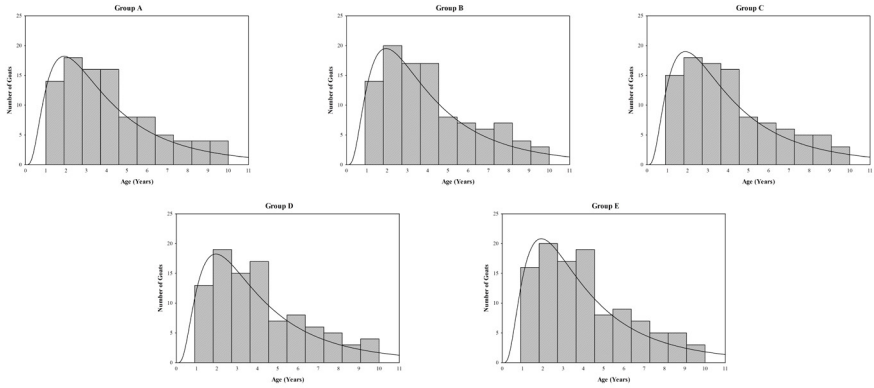


Figure 3. Age distribution of 96 Aspromontana (Group A), 102 Girgentana (Group B), 99 Messinese (Group C), 96 Maltese (Group D) and 108 Argentata dell'Etna (Group E) goats

Table 1. Number and body weight (bw) expressed as mean ± standard deviation (SD) of goats divided according to their breed (Aspromontana, Girgentana, Messinese, Maltese and Argentata dell'Etna) and age (1–2 years, 3–4 years and >5 years)

Breed (Total number=501)	Age class		
	I (1–2 years)	II (3–4 years)	III (>5 years)
Aspromontana (n=96)	A_I (n=32; bw=29±5 kg)	A_{II} (n=32; bw=40±3 kg)	A_{III} (n=32; bw=44±3 kg)
Girgentana (n=102)	B_I (n=34; bw=29±3 kg)	B_{II} (n=34; bw=37±4 kg)	B_{III} (n=34; bw=43±3 kg)
Messinese (n=99)	C_I (n=33; bw=22±4 kg)	C_{II} (n=33; bw=35±3 kg)	C_{III} (n=33; bw=37±2 kg)
Maltese (n=96)	D_I (n=32; bw=28±4 kg)	D_{II} (n=32; bw=38±4 kg)	D_{III} (n=32; bw=42±4 kg)
Argentata dell'Etna (n=108)	E_I (n=36; bw=25±3 kg)	E_{II} (n=36; bw=35±3 kg)	E_{III} (n=36; bw=38±2 kg)

Blood sampling and analysis

Blood samples were collected from each goat by jugular venipuncture into 3-mL vacutainer tubes (Terumo Corporation) containing ethylenediaminetetraacetic acid (EDTA).

Blood sampling was performed in the morning at the same hour in order to minimize the influence of circadian rhythms (Piccione and Caola, 2002).

EDTA whole blood samples were delivered to the laboratory and processed within 2 hours. From the blood samples, Red Blood Cell (RBC), White Blood Cell (WBC), Hemoglobin concentration (Hb), Hematocrit (Hct), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC) and Platelets (PLT) were assessed with an automated hematology analyzer (HeCo Vet C, SEAC, Florence, Italy) using a concentrated lysing reagent for ovine species (SEAC, Radim Company, Calenzano, Italy).

Two blood smears for each sample were made and microscopically examined for platelet clumps and visual verification. Moreover, a manual RBC, WBC and PLT count was performed to verify and validate the automated count. The manual counts of RBC, WBC and PLT were reported if microscopic examination did not verify the automated count.

Protocols of animal husbandry and experimentation were reviewed and approved in accordance with the standards recommended by the Guide for the Care and Use of Laboratory Animals and Directive 2010/63/EU for animal experiments.

Statistical analysis

Obtained values were tested for normality using the Anderson-Darling normality test. Hematological data were analyzed using Reference Value Advisor (Geffre et al., 2001). Particularly, histograms were examined for estimation of data distribution and to identify the presence of outliers.

Upper (97.5th percentile) and lower (2.5th percentile) limits were established nonparametrically and 90% confidence intervals (CI) were determined nonparametrically around these limits.

One-way analysis of variances (ANOVA) followed by Duncan's post hoc comparison test was applied on hematological values obtained from goat's groups in order to determine the breed's effect. Afterwards, two-way ANOVA, followed by Duncan's post hoc comparison test, was applied between subgroups to determine the significant differences between breeds at the same age class, and to evaluate the statistical effects of age within the same group on RBC, Hb, Hct, MCV, MCH, MCHC, WBC and PLT.

P-value<0.05 was considered statistically significant. Statistical analysis was performed using the STATISTICA 7 software package (Stat Software Inc., Tulsa, Oklahoma, USA).

Results

The RBC, WBC and PLT's manual count validated the results obtained from automated count.

Data were normally distributed (P>0.05, Anderson–Darling normality test) with a Gaussian distribution and no outlier values were found.

Table 2. Nonparametric hematologic reference intervals (RI) for healthy female Aspromontana (Group A), Girgentana (Group B), Messinese (Group C), Maltese (Group D) and Argentata dell'Etna (Group E) goats

Hematologic variable	Group	Descriptive statistics		RI within 90% CI			N	Distribution
		mean±SD	min/max	RI	Limit			
					lower	upper		
RBC (10^6/μL)	A a	15.5±1.6	12.1–19.0	12.2–18.1	12.1–12.7	17.9–19.0	96	G
	B a	15.5±2.0	11.2–20.6	11.7–20.1	11.2–12.5	18.8–20.6	102	G
	C	17.1±2.1	11.4–21.7	12.2–21.2	11.4–13.4	20.1–21.7	99	G
	D	17.3±2.0	13.1–24.0	13.8–23.0	13.1–14.0	20.4–24.0	96	G
	E	17.2±2.4	11–25	11.3–22.6	11.0–13.5	21–25	108	G
Hb (g/dL)	A b	9.3±1.1	7.4–12.6	7.4–12.0	7.4–7.8	11.0–12.6	96	G
	B	10.3±2.3	6.8–17.3	7.2–16.1	6.8–7.8	15.4–17.3	102	G
	C d	11.5±2.0	6.9–16.3	7.0–15.4	6.9–8.1	14.7–16.3	99	G
	D	10.5±1.3	7.0–13.6	7.4–12.8	7.0–8.1	12.4–13.6	96	G
	E c	14.4±1.7	10.0–18.9	11–18	10.0–11.7	17.5–18.9	108	G
Hct (%)	A d	27.6±1.9	22.0–32.2	22.8–32.0	22.0–25.0	31.0–32.2	96	G
	B e	24.8±3.5	19–35	20.0–32.3	19.0–20.4	30.7–35.0	102	G
	C	26.8±3.6	20.3–35.0	20.6–34.1	20.3–21.2	32.3–35.0	99	G
	D	25.5±2.4	19.8–30.0	20.5–30.0	19.8–20.8	29.2–30.0	96	G
	E c	28.7±3.6	20–35	20.8–34.3	20.0–22.5	33.2–35.0	108	G
MCV (fL)	A c	18.0±1.9	13.4–23.2	14.3–22.9	13.4–15.1	21.9–23.2	96	G
	B	15.4±1.3	12.3–18.3	12.8–18.1	12.3–13.5	17.7–18.3	102	G
	C	15.7±2.2	11.6–21.1	11.9–20.7	11.6–12.4	19.8–21.1	99	G
	D	14.9±1.9	8.9–20.0	9.9–19.1	8.9–11.8	18.1–20.0	96	G
	E c	17.1±3.4	11.1–30.0	11.2–26.8	11.1–11.5	22.2–30.0	108	G

MCH (pg)	A g	6.0±0.6	4.5–8.4	4.8–7.6	4.6–5.1	7.0–8.4	96	G
	B	6.6±0.8	5.4–8.4	5.5–8.3	5.4–5.6	8.1–8.4	102	G
	C h	6.7±1.0	4.5–8.9	4.9–8.8	4.5–5.3	8.5–8.9	99	G
	D	6.2±1.0	3.5–8.8	3.8–8.3	3.5–4.6	8.0–8.8	96	G
	E f	8.5±1.6	5.4–13.8	5.9–12.8	5.4–6.4	11.1–13.8	108	G
MCHC (g/dL)	A b	33.7±3.7	26.3–44.1	26.6–43.8	26.3–27.7	40.9–44.1	96	G
	B	41.5±5.8	26–56	29.2–51.7	26–32	49.6–56.0	102	G
	C	42.9±4.3	32.8–52.9	33.1–51.1	32.8–35.8	50.6–52.9	99	G
	D	41.7±6.9	25.7–60.0	29.3–58.0	25.7–31.2	54.7–60.0	96	G
	E c	50.9±8.6	32.7–85.0	34.7–72.4	32.7–38.6	66.1–85.0	108	G
WBC (10^3/μL)	A	10.2±1.8	6.8–14.9	7.2–13.6	6.8–7.7	13.1–14.9	96	G
	B	10.4±1.8	6.1–15.0	6.8–14.0	6.1–7.3	13–15	102	G
	C	9.8±2.1	4.2–15.3	5.1–14.3	4.2–6.4	13.6–15.3	99	G
	D	10.1±2.4	4.4–15	5.1–15	4.4–6.0	14.3–15.0	96	G
	E	9.9±2.1	5.3–18.1	6.5–15.2	5.3–7.1	12.9–18.1	108	G
PLT (10^3/μL)	A c	235.4±75.4	100–422	108.4–379.4	100.0–132.2	349.6–422.0	96	G
	B h	173.7±33.2	110–254	115–250	110.0–121.7	238.4–254.0	102	G
	C	196.2±40.8	103–295	114.5–278.1	103.0–127.8	266.5–295.0	99	G
	D	209.6±71.7	100–396	109.2–391.0	100–118	350–396	96	G
	E c	236.0±71.7	112–431	121–409	112–121	364.4–431.0	108	G

SD – standard deviation; CI – confidence interval; min – minimum; max – maximum; N – number of samples; G – Gaussian distribution.

Significant effect of breed ($P<0.01$): a vs Groups C, D and E; b vs Groups B, C, D and E; c vs Groups B, C and D; d vs Groups B and D; e vs Groups C and D; f vs Groups A, B, C and D; g vs Groups B and C; h vs Group D.

Mean values ± standard deviation (SD), descriptive statistics and reference intervals (RI) of hematological parameters measured in goat breeds are shown in Table 2. One-way ANOVA showed significant differences (P<0.01) in RBC, Hb, Hct, MCV, MCH, MCHC, and PLT values among the five breeds, while no effect of breed on WBC values was shown (Table 2).

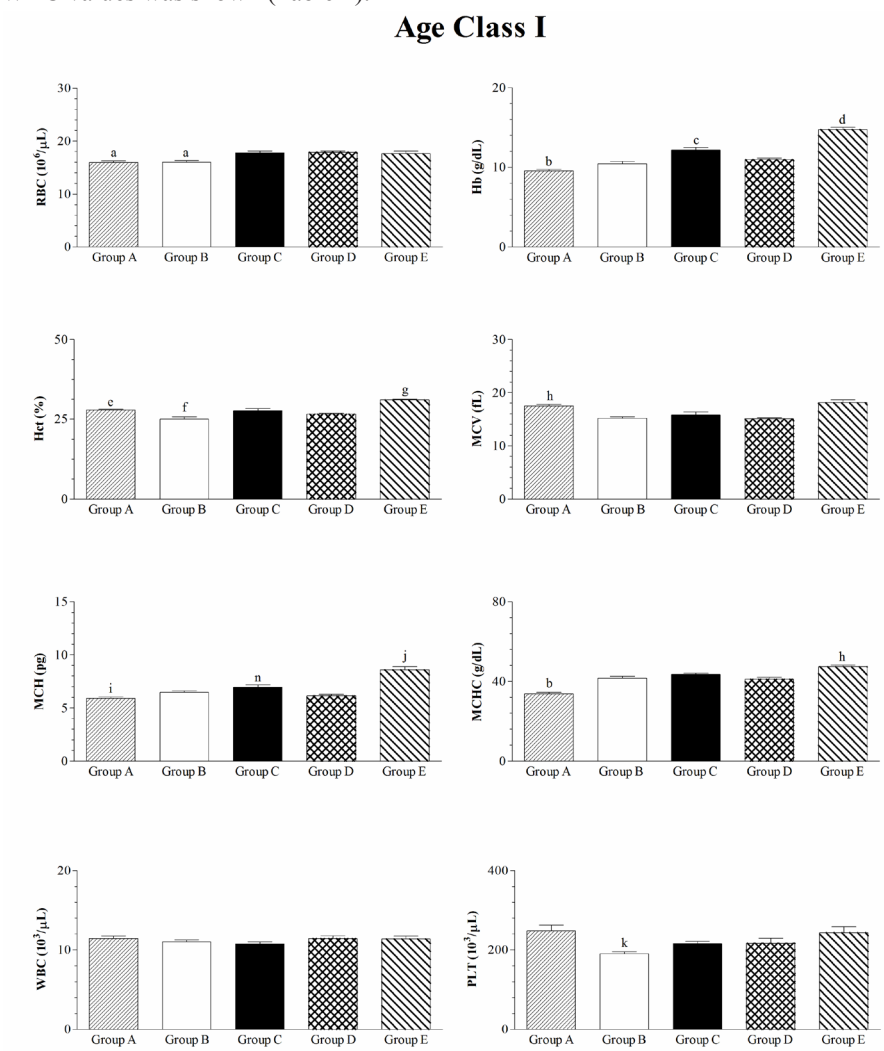
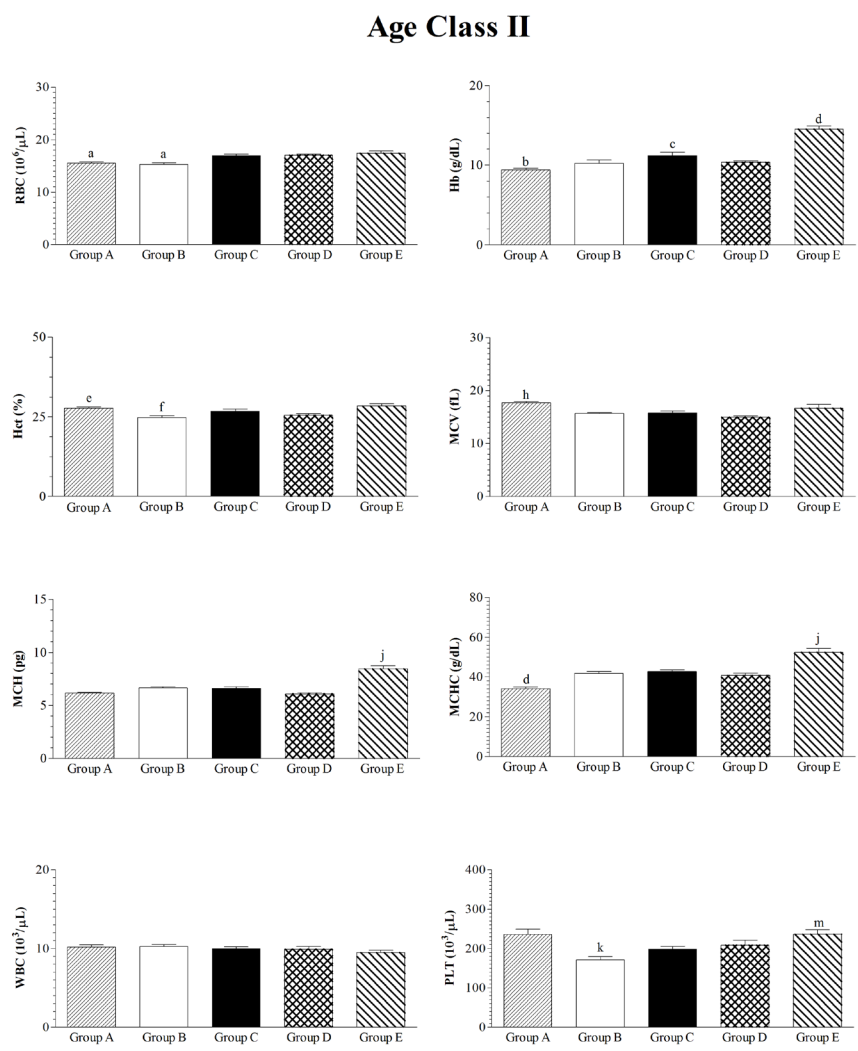
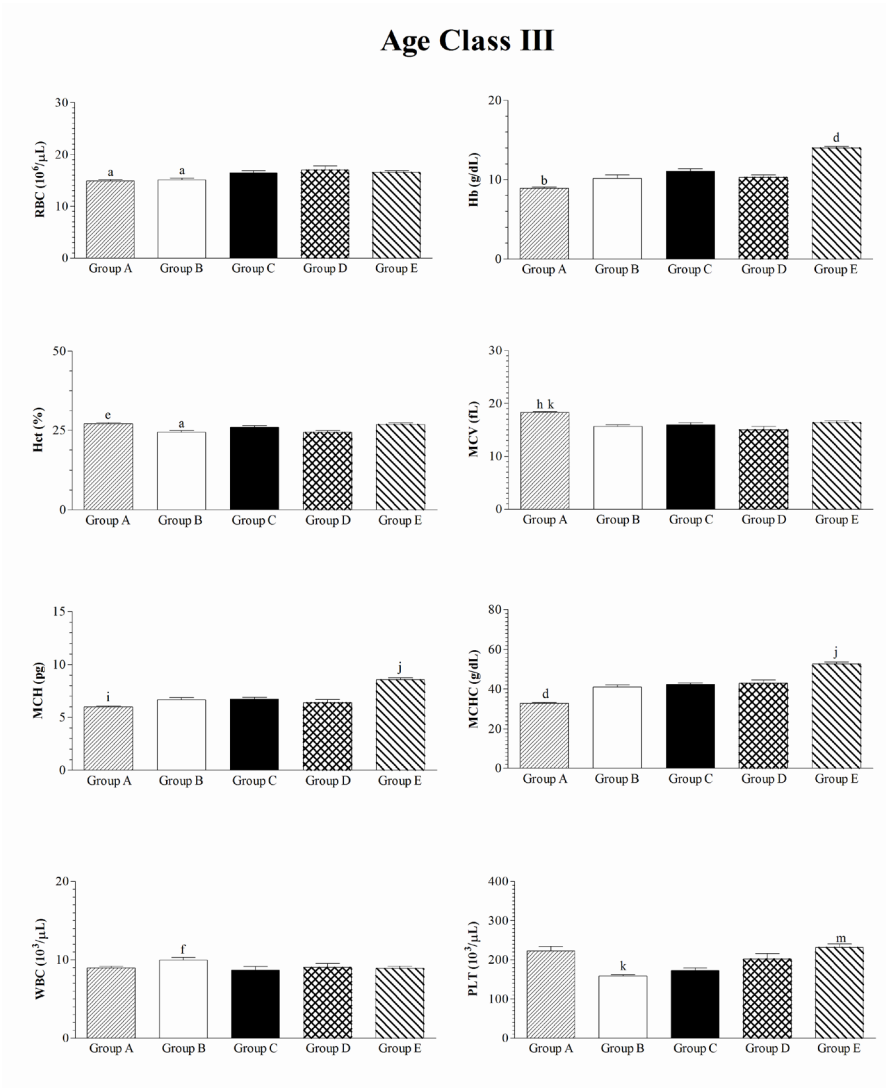


Figure 4. Effect of breed on hematological parameters in Aspromontana (Group A), Girgentana (Group B), Messinese (Group C), Maltese (Group D) and Argentata dell'Etna (Group E) goats of age class I (1–2 years)



Significant Effect of Breed (P<0.01): a vs Groups C, D and E; b vs Groups B, C and E; c vs Group B; d vs Groups B, C and D; e vs Groups B, C, D and E; f vs Group E; h vs Groups B, C and D; j vs Groups A, B, C and D; k vs Groups A, D and E; m vs Groups A and E

Figure 5. Effect of breed on hematological parameters in Aspromontana (Group A), Girgentana (Group B), Messinese (Group C), Maltese (Group D) and Argentata dell'Etna (Group E) goats of age class II (3–4 years)



Significant Effect of Breed (P<0.01): a vs Groups C, D and E; b vs Groups B, C and E; c vs Groups B and D; d vs Groups B, C and D; f vs Groups C and E; h vs Groups B, C and D; i vs Groups B and C; j vs Groups A, B, C and D; k vs Groups A, E and D; m vs Groups A and E

Figure 6. Effect of breed on hematological parameters in Aspromontana (Group A), Girgentana (Group B), Messinese (Group C), Maltese (Group D) and Argentata dell'Etna (Group E) goats of age class III (>5 years)

Table 3. Mean values ± standard error of the mean (M±SEM) of hematological parameters recorded in Aspromontana (Groups A_I, A_{II}, A_{III}), Girgentana (Groups B_I, B_{II}, B_{III}), Messinese (Groups C_I, C_{II}, C_{III}), Maltese (Groups D_I, D_{II}, D_{III}) and Argentata dell'Etna (Groups E_I, E_{II}, E_{III}) goats

Groups		Hematological parameters							
		RBC (10^6/µL)	Hb (g/dL)	Hct (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)	WBC (10^3/µL)	PLT (10^3/µL)
1–2 years	A_I	15.98±0.28	9.43±0.21	27.90±0.26	17.63±0.26	5.94±0.14	33.82±0.70	11.47±0.31 ab	248.54±14.26
	B_I	16.02±0.31	10.42±0.34	25.06±0.76	14.96±0.20	6.54±0.13	41.68±1.15	11.02±0.29 c	190.80±4.91 c
	C_I	17.79±0.37 d	12.16±0.34 d	27.63±0.67	15.97±0.56	6.93±0.25	43.54±1.42	10.79±0.26 d	216.30±5.46 d
	D_I	17.90±0.20	10.96±0.20	26.65±0.25	14.96±0.26	6.15±0.14	41.21±0.78	11.45±0.34	217.63±12.05
	E_I	17.64±0.49	14.72±0.26	31.10±0.26 f	18.14±0.57 g	8.55±0.31	47.39±0.85 g	11.42±0.34 g	243.44±14.93
3–4 years	A_{II}	15.54±0.25	9.54±0.20	27.77±0.39	18.00±0.23	6.14±0.08	34.26±0.90	10.21±0.24 a	235.88±13.59
	B_{II}	15.29±0.35	10.23±0.39	24.77±0.62	15.68±0.18	6.64±0.12	41.84±1.02	10.25±0.26	171.31±7.46
	C_{II}	16.98±0.27	11.25±0.36	26.79±0.69	15.76±0.37	6.58±0.16	42.73±1.08	9.99±0.23 d	198.59±6.78
	D_{II}	17.08±0.18	10.38±0.17	25.58±0.35	15.01±0.23	6.09±0.11	40.88±1.01	9.92±0.32	208.84±13.07
	E_{II}	17.44±0.39	14.55±0.35	28.38±0.71	16.70±0.68	8.45±0.28	52.52±1.91	9.50±0.29	236.44±11.98
>5 years	A_{III}	14.87±0.27	8.91±0.16	27.10±0.35	18.34±0.19	6.01±0.08	32.89±0.43	8.98±0.21	222.22±11.83
	B_{III}	15.10±0.34	10.16±0.46	24.43±0.69	15.37±0.28	6.63±0.20	40.99±1.01	9.94±0.36	158.43±3.41
	C_{III}	16.47±0.39	11.05±0.32	25.99±0.56	15.50±0.37	6.68±0.17	42.35±0.99	8.69±0.45	172.55±6.94
	D_{III}	17.00±0.80	10.31±0.30	24.43±0.67e	14.73±0.64	6.23±0.28	42.94±1.62	9.02±0.52 e	202.15±14.40
	E_{III}	16.55±0.32	13.99±0.21	26.88±0.51	16.39±0.36	8.56±0.19	52.59±1.13	8.91±0.27	231.72±8.84

Significant effect of age ($P<0.05$): a vs Group A_{III}; b vs Group A_{II}; c vs Group B_{III}; d vs Group C_{III}; e vs Group D_I, D_{II}; f vs Groups E_{II}, E_{III}; g vs Groups E_{II}, E_{III}.

Two-way ANOVA showed significant differences between breeds ($P<0.05$) at the same age class for all studied hematological parameters (Figures 4, 5 and 6). In particular, the RBC levels were lower in Aspromontana and Girgentana breeds than Messinese, Maltese and Argentata dell'Etna breeds at all age classes. Hb showed lower levels in Aspromontana breed than Girgentana (Subgroups B_I, B_{II}, B_{III}), Messinese (Subgroups C_I, C_{II}, C_{III}), Maltese (Subgroup D_I) and Argentata dell'Etna (Subgroups E_I, E_{II}, E_{III}) breeds. Hb showed also higher levels in Messinese than Girgentana (Subgroups B_I, B_{II}) and Messinese (Subgroup D_I) breeds, and in Argentata dell'Etna compared to Girgentana, Messinese and Maltese breeds at all age classes. Higher Hct values were found in Aspromontana than Girgentana (Subgroups B_I,B_{II}, B_{III}) and Messinese (Subgroups C_{II}, C_{III}) breeds. Girgentana and Maltese breeds showed lower Hct levels compared to Messinese and Argentata dell'Etna breeds at all age classes, while higher Hct values were found in Argentata dell'Etna than Aspromontana (Subgroup A_I), Messinese (Subgroup C_I) and Maltese (Subgroup D_I) breeds.

MCV showed higher values in Aspromontana compared to Girgentana (Subgroups B_I, B_{II}, B_{III}), Messinese (Subgroups C_I, C_{II}, C_{III}) and Maltese (Subgroups D_I, D_{II}, D_{III}) breeds at all age classes, and compared to Argentata dell'Etna breed at the first age class only (Subgroup E_I). In addition, higher MCV levels were found in Argentata dell'Etna than Girgentana (Subgroup B_I), Messinese (Subgroup C_I) and Maltese (Subgroups D_I, D_{II}, D_{III}) breeds. MCH showed lower values in Aspromontana compared to Girgentana (Groups B_I, B_{III}) and Messinese (Subgroups C_I, C_{III}), and higher values in Argentata dell'Etna breed than the other breeds at all age classes. MCHC showed lower values in Aspromontana compared to Girgentana (Subgroups B_I, B_{II}, B_{III}), Messinese (Subgroups C_I, C_{II}, C_{III}) and Maltese (Subgroups D_I, D_{II}, D_{III}) breeds. Higher MCHC values in Argentata dell'Etna than Aspromontana, Girgentana, Messinese and Maltese breeds were found at all age classes.

Higher WBC levels were found in Girgentana than Messinese (Subgroup C_{III}) and Argentata dell'Etna (Subgroup E_{III}) breeds. PLT showed lower values in Girgentana than Aspromontana (Subgroups A_I, A_{II}, A_{III}), Maltese (Subgroups D_{II}, D_{III}) and Argentata dell'Etna (Subgroups E_{II}, E_{III}) breeds, and in Messinese than Aspromontana (Subgroups A_{II}, A_{III}) and Argentata dell'Etna (Subgroups E_{II}, E_{III}) breeds.

Moreover, the effect of age ($P<0.05$) on RBC, Hb, Hct, MCV, MCHC, WBC and PLT was found (Table 3).

Discussion

Although it is well established that ambient temperature as well as THI and the other climatic conditions affect biochemical and hematological parameters in goat, in the present study, the five farms showed very similar values of ambient temperature, relative humidity, rainfall and THI.

The ideal ambient temperature ("thermoneutral" zone) for a goat is between 12°C and 24°C (Nikitchenko et al., 1998). As ambient temperature increases, it becomes more difficult for a goat to cool herself adequately and enters heat stress. THI cal-

culated for the five farms ranged from 63.70 to 65.44. THI values of 70 or less are considered comfortable, 75–78 stressful, and values greater than 78 cause extreme distress with goats being unable to maintain thermoregulatory mechanisms or normal body temperatures (Di Grigoli et al., 2009).

This excludes the effect of autumn environmental variables on hematological parameters considered.

All hematological data obtained in the present study are within the physiological range for goats (Weiss and Wardrop, 2010) and agree with the findings of other studies carried out on Aspromontana and Girgentana breeds (Piccione et al., 2010, 2014). In contrast, the data obtained for the Messinese, Maltese and Argentata dell'Etna goats are the first reference values to be published.

According to previous studies our findings highlighted that the influence of breed and age should be considered when evaluating goat's hematology (Addass et al., 2010; Okonkwo et al., 2011; Piccione et al., 2014).

The lack of differences in the environmental variables among the five farms suggests that the differences found in hematological parameters studied in goat groups were attributable exclusively to the different goat breeds and age.

The lowest RBC and Hb values were found in Aspromontana and Girgentana goats while Messinese, Maltese and Argentata dell'Etna goats showed the highest levels.

Hct showed the lowest values in Girgentana goat, while the highest levels were found in Argentata dell'Etna goat. MCV and PLT values were highest in Aspromontana and Argentata dell'Etna goats. MCH and MCHC showed the lowest values in Aspromontana breed while the highest values were found in Argentata dell'Etna breed.

These findings suggest that Messinese, Maltese and Argentata dell'Etna goats have greater propensity to transport oxygen and in situation of oxygen starvation, these breeds survive better as previously suggested by Okonkwo et al. (2011).

The changes found in RBC, Hb and Hct values explain the variations obtained on the erythrocyte indices (MCV, MCH and MCHC) among the breeds.

The differences due to age are a signal of the health status of the various age groups among the goat breeds studied, which is in agreement with the findings of other authors (Addass et al., 2010; Islam et al., 2004; Ismailov, 2005; Weiss and Wardrop, 2010).

The results of the present study indicated that younger Messinese goats (Subgroups C_I) had more erythrocytes and higher Hb concentration than older Messinese goats (Subgroup CIII). This is in accordance with a previous study (Piccione et al., 2010) carried out on the same goat breed. On the contrary, other authors (Daramola et al., 2005) reported higher RBC values in adult West African Dwarf goats than in young West African Dwarf goats. Age-related changes were observed in MCV and MCHC of Argentata dell'Etna goats. In particular, MCV was highest in younger goats (Subgroup E_I) and decreased with age (Subgroups E_{II} and E_{III}), while MCHC was lowest in younger goats (Subgroup E_I) and increased with age (Subgroups E_{II} and E_{III}). A significant age-effect on Hct values in Maltese and Argentata dell'Etna goats was observed with higher levels found in younger than older goats.

The differences in erythrocyte indices observed among the age classes of the studied goats suggested that the oxygen carrying capacity of the blood was higher in young goats than in the old ones (Daramola et al., 2005).

Additionally, age was observed to have significant effect on WBC in all considered goat breeds. Higher WBC values were found in younger goats compared to older goats, in contrast to other studies that reported higher WBC values in adult West African Dwarf goats (Daramola et al., 2005). According to other authors (Watson et al., 1994; Weiss and Wardrop, 2010; Piccione et al., 2014), there are age-dependent immune variations in animals, and, younger goats seem to possess a suitable protective system, providing a rapid and potent defense against any infectious agent.

PLT levels were higher in younger than older goats as well. Particularly, Girgentana and Messinese goats aged 1–2 years (Subgroups B_I and C_I, respectively) showed higher PLT values than >5-year-old goats (Subgroups B_{III} and C_{III}, respectively). PLT play a critical role in the prevention of blood loss and are major contributors to thrombosis, inflammation and neoplasia (Weiss and Wardrop, 2010; Okonkwo et al., 2011).

Thrombocytopenia (severe decrease in PLT) is associated with a bleeding tendency, while thrombocytosis (increase in PLT) may follow hemorrhage, surgery or fracture of bone. However, the PLT values of all studied goats fall within the normal range of 160–490 $\times 10^3/\mu L$ (Weiss and Wardrop, 2010).

Conclusions

Hematological parameters in healthy goats show several variations in relation to breed and age. The establishment of reference values of hematological parameters is essential for evaluating the health and physiological status of farm animals. Establishing and utilizing breed-specific reference intervals for all goat breeds would be challenging for the laboratory and veterinarian alike, but knowledge of differences in certain analytes for breed types is essential to clinical interpretation of blood values. Our findings show that a great variation in goat's hematology exists among different breeds and age classes, therefore, any changes in hematological variables must be assessed in relation to these factors. The results obtained in the present study increase our understanding of hematology of Aspromontana, Girgentana, Messinese, Maltese and Argentata dell'Etna goats and may serve as reference values which could help veterinarians to interpret laboratory data appropriately and to monitor animal's health status, in order to improve the management and conservation of these breeds.

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