Physiological and Biochemical Profile of Housed Hu Sheep in the Zizhong Area of Sichuan Province in Summer

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Abstract [**Objectives**] This study was conducted to evaluate the physiological adaptability of housed Hu sheep introduced to the Zizhong area of Sichuan Province under high-temperature summer conditions. [**Methods**] Adult male and female Hu sheep (10 per group) reared in a housing system in this region were assessed by measuring physiological, hematological and blood biochemical parameters. [**Results**] The body temperature of rams was significantly higher than that of ewes ($P<0.05$), whereas no significant differences were observed between rams and ewes in respiratory rate or heart rate ($P>0.05$). Ewes exhibited significantly higher values than rams in several blood physiological parameters, including total leukocyte count, lymphocyte count, hemoglobin content, hematocrit, and mean corpuscular hemoglobin content ($P<0.05$). No significant differences were detected in the remaining six blood physiological parameters between rams and ewes. Regarding blood biochemical indicators, ewes showed significantly elevated levels of albumin, cholesterol, alkaline phosphatase, and the blood urea nitrogen/creatinine ratio ($P<0.05$), while rams had significantly higher creatinine content ($P<0.05$). No significant differences were found between sexes in other 11 blood biochemical indicators, including total protein, globulin, and glucose. These findings suggest that under summer conditions in the Zizhong area, housed Hu sheep exhibit sex-based differences in physiological adaptability, with ewes displaying enhanced blood oxygen-carrying capacity and immune-related indicators compared to rams. [**Conclusions**] The study provides valuable insights for understanding the adaptation mechanisms of Hu sheep and developing gender-specific management strategies during subtropical summers.

Key words Hu sheep; Physiological parameter; Biochemical parameter; Respiratory rate; Heart rate; Temperature
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The Hu sheep is a renowned indigenous multiparous sheep breed in China. It is characterized by rapid early growth, early sexual maturity, year-round estrus, high fecundity, and good lactation performance. The breed is also famous worldwide for the attractive patterned pelts obtained from lambs slaughtered 1 – 2 dafter birth. Its central production area includes Wuxing, Nanxun, and Changxing in Huzhou City, Zhejiang Province, Tongxiang, Xiuzhou, Nanhu, and Haining in Jiaxing City, and Wuzhong, Taicang, and Wujiang counties in Jiangsu Province within the Taihu Lake basin[1]. It serves as a precious national livestock genetic resource in China. In recent years, the Hu sheep has been promoted throughout China due to its excellent production performance and strong adaptability. It has been used in purebred rearing and crossbreeding improvement, effectively driving the development of the mutton sheep industry.

Animal blood physiological and biochemical parameters reflect the health status of the organism. Generally, these parameters are measured to assess normal physiological functions and metabolic conditions based on their variations[2]. Under normal circumstances, an animal's blood physiological and biochemical parameters are maintained at a relatively stable and healthy level. However, they can be influenced by multiple factors such as age, sex, nutritional level, physiological status, and living environment[3]. When a livestock or poultry breed is introduced to a new region, its physiological functions may adapt to the new environment, leading to differences from those in its place of origin. Blood physiological and biochemical parameters can serve as criteria to assess whether the breed has successfully adapted to the new region[4].

In recent years, Hu sheep have been introduced to regions including Henan[5], the high-cold areas of Northwest China[6], Chongqing[7], and Liangshan Prefecture in Sichuan[8], where they have demonstrated good adaptability to local climatic and forage conditions. Located in the inland southwest of China, Sichuan has abundant feed resources such as crop straw and pasture, providing favorable conditions for rearing introduced Hu sheep. Whether introduced Hu sheep can adapt to Sichuan's climate and forage environment needs to be evaluated from the perspective of their physiological functions. Therefore, in this study, Hu sheep that had been acclimatized and raised for over one year in the Zizhong area of Sichuan Province were selected as research subjects, and their physiological and blood physiological and biochemical parameters were measured in summer to assess whether they had successfully adapted to the local climate and forage conditions.

Materials and Methods

Experimental animals

Hu sheep introduced to the Zizhong area of Sichuan were selected as the object of study. These introduced Hu sheep had been raised in the Zizhong area for at least one year. From the adult male and female flocks, 10 healthy rams and 10 healthy ewes aged 3 – 5 years were chosen, totaling 20 sheep. They were housed and fed using a "concentrate + hay" feeding method, with free access to water.

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Physiological indicators

In July 2022, between 6:00 and 8:00 a.m., with the environment kept quiet and the sheep restrained in a calm state, the rectal temperature, heart rate, and respiratory rate of both male and female Hu sheep were measured.

Blood sample collection

In the morning, with the sheep in a fasting state, 6 - 8 ml of blood was collected from the jugular vein using a syringe. Then, 3 - 4 ml of the blood was injected into a 5 ml vacuum blood collection tube containing EDTA-K2 anticoagulant, which was then gently inverted to mix well. The remaining blood was injected into another vacuum blood collection tube without anticoagulant and allowed to coagulate naturally. All collected samples were stored at low temperatures and promptly sent for testing.

Statistical analysis

Raw data were processed using Excel. Statistical analysis was performed using IBM SPSS Statistics 22, and the results were expressed as mean ± standard deviation ($\bar{x} \pm S$).

Results and Analysis

Physiological indicators

As shown in Table 1, for Hu sheep introduced to the Zizhong area, the body temperatures of rams and ewes in summer were (39.89 ± 0.30) and (39.11 ± 0.16) ℃, respectively. The body temperature of rams was significantly higher than that of ewes ($P < 0.05$), though both values remained within the normal physiological range for sheep. The respiratory rates were (67.00 ± 3.74) breaths/min for rams and (69.20 ± 7.81) breaths/min for ewes, with no significant difference between sexes ($P > 0.05$). The heart rates were (73.00 ± 1.63) beats/min for rams and (79.90 ± 11.00) beats/min for ewes, also showing no significant difference between sexes ($P > 0.05$).

Table 1 Physiological parameters of Hu sheep in summer

Sex	Sample No. (N)	Body temperature//℃	Respiratory rate breaths/min	Heart rate beats/min
Ram	10	39.89 ± 0.30	67.00 ± 3.74	73.00 ± 1.63
Ewe	10	39.11 ± 0.16	69.20 ± 6.52	79.90 ± 11.00
P value		0.00	0.75	0.65

Hematological parameters

As shown in Table 2, for Hu sheep introduced to the Zizhong area and raised under house-feeding conditions, the hemoglobin content was (140.40 ± 9.41) g/L in rams and (155.90 ± 16.15) g/L in ewes in summer. The total red blood cell count was (12.21 ± 0.77) $\times 10^{12}$/L in rams and (12.99 ± 0.93) $\times 10^{12}$/L in ewes. The total white blood cell count was (124.46 ± 13.09) $\times 10^{9}$/L in rams and (164.97 ± 13.14) $\times 10^{9}$/L in ewes. The lymphocyte count was (114.69 ± 9.04) $\times 10^{9}$/L in rams and (153.45 ± 13.08) $\times 10^{9}$/L in ewes. The total platelet count was (383.90 ± 29.19) $\times 10^{9}$/L in rams and (383.90 ± 26.98) $\times 10^{9}$/L in ewes. No significant differences were observed between rams and ewes in blood physiological parameters such as lymphocyte percentage, total red blood cell count, mean corpuscular volume, mean corpuscular hemoglobin concentration, red blood cell distribution width-coefficient of variation, and total platelet count ($P > 0.05$). However, ewes exhibited significantly higher values than rams in total white blood cell count, lymphocyte count, hemoglobin content, hematocrit, and mean corpuscular hemoglobin content ($P < 0.05$).

Blood biochemical parameters

As shown in Table 3, for Hu sheep raised under house-feeding conditions in the Zizhong area, the following blood biochemical parameters were recorded for rams and ewes, respectively: alanine aminotransferase content, (19.20 ± 1.67) and (31.50 ± 2.32) U/L; alkaline phosphatase content, (152.40 ± 14.29) and (291.70 ± 23.48) U/L; creatine kinase content, (203.10 ± 18.51) and (218.60 ± 20.94) U/L; creatinine content, (79.20 ± 5.89) and (44.30 ± 3.37) μmol/L; cholesterol content, (2.20 ± 0.22) and (4.07 ± 0.37) mmol/L; glucose content, (3.39 ± 0.33) and (5.03 ± 0.44) mmol/L; total protein content, (82.08 ± 6.78) and (81.14 ± 7.12) g/L; albumin content, (30.53 ± 2.38) and (34.55 ± 3.14) g/L; globulin content, (51.55 ± 4.29) and (46.59 ± 3.32) g/L; and calcium content, (2.44 ± 0.19) and (2.14 ± 0.18) mmol/L. No significant differences were observed between rams and ewes in blood biochemical parameters such as total protein, globulin, albumin/globulin ratio, calcium, glucose, urea nitrogen, inorganic phosphorus, amylase, alanine aminotransferase, total bilirubin, and creatine kinase ($P > 0.05$). However, ewes exhibited significantly higher values than rams in albumin, cholesterol, alkaline phosphatase, and urea nitrogen/creatinine ratio ($P < 0.05$), while rams had significantly higher creatinine levels than ewes ($P < 0.05$).

Table 2 Hematological parameters of Hu sheep in summer

Sex	Sample No. (N)	Total white blood cell count//10^9/L	Lymphocyte count//10^9/L	Lymphocyte percentage//%	Hemoglobin concentration//g/L	Total red blood cell count//10^{12}/L	Hematocrit %
Ram	10	124.46 ± 13.09	114.69 ± 9.04	91.78 ± 2.43	140.40 ± 9.41	12.21 ± 0.77	49.70 ± 2.44
Ewe	10	164.97 ± 13.14	153.45 ± 13.08	92.85 ± 1.85	155.90 ± 16.15	12.99 ± 0.93	52.69 ± 3.12
P value		0.007	0.009	0.283	0.02	0.06	0.03

Sex	Sample No. (N)	Mean corpuscular volume (MCV)//fl	Mean corpuscular hemoglobin (MCH)//pg	Mean corpuscular hemoglobin concentration (MCHC)//g/L	Red cell distribution width-coefficient of variation (RDW-CV)//%	Total platelet count//10^9/L
Ram	10	40.78 ± 2.38	11.49 ± 0.43	251.93 ± 17.39	9.86 ± 0.25	383.90 ± 29.19
Ewe	10	40.62 ± 1.57	11.99 ± 0.59	295.29 ± 16.23	9.87 ± 0.26	383.90 ± 26.98
P value		0.86	0.04	0.14	0.931	0.95

Table 3 Blood biochemical parameters of Hu sheep in summer

Sex	Sample No. (N)	Albumin g/L	Total protein g/L	Globulin g/L	Albumin-to-globulin ratio (A/G ratio)	Calcium (Ca) mmol/L	Glucose (Glu) mmol/L	Blood urea nitrogen (BUN) mmol/L	Inorganic phosphorus (IP) mmol/L
Ram	10	30.53 ±2.38	82.08 ±6.78	51.55 ±4.29	0.60 ±0.04	2.44 ±0.19	3.39 ±0.33	4.44 ±0.42	2.11 ±0.29
Ewe	10	34.55 ±3.14	81.14 ±7.12	46.59 ±3.32	0.89 ±0.06	2.14 ±0.18	5.03 ±0.44	5.01 ±0.51	2.08 ±0.37
P value		0.025	0.796	0.320	0.193	0.262	0.262	0.433	0.834
Sex	Sample No. (N)	Amylase (AMS) // U/L	Cholesterol (CHOL) mmol/L	Alanine amino-transferase (ALT) // U/L	Total bilirubin (TBIL) umol/L	Alkaline phosphatase (ALP) // U/L	Creatinine (CREA) umol/L	Urea nitrogen-to-creatinine ratio (BUN/CREA ratio)	Creatine kinase (CK) U/L
Ram	10	20.50 ±2.31	2.20 ±0.22	19.20 ±1.67	7.27 ±0.58	152.40 ±14.29	79.20 ±5.89	14.00 ±1.16	203.10 ±18.51
Ewe	10	51.90 ±5.21	4.07 ±0.37	31.50 ±2.32	7.55 ±0.61	291.70 ±23.48	44.30 ±3.37	25.80 ±2.35	218.60 ±20.94
P value		0.109	0.015	0.056	0.840	0.000	0.000	0.003	0.658

Conclusions and Discussion

Physiological indicators in livestock and poultry primarily include three parameters: heart rate, respiratory rate, and body temperature. These indicators reflect cardiac function and the metabolic level of the body, as well as inflammatory responses, metabolic abnormalities, the condition of the respiratory system, and the body's metabolic demands. They exhibit relative stability. Once changes occur, they indicate alterations in the animal's metabolism and physiological or pathological state[9]. In this study, Hu sheep raised in the Zizhong area in summer exhibited following physiological parameters: heart rate, (73.00 ± 1.63) beats/min in rams and (79.90 ± 11.00) beats/min in ewes; respiratory rate, (67.00 ± 3.74) breaths/min in rams and (69.20 ± 7.81) breaths/min in ewes; and body temperature, (39.89 ± 0.30) ℃ in rams and (39.11 ± 0.16) ℃ in ewes. Based on these indicators, the physiological parameters of Hu sheep raised in this area in summer were relatively stable and fell within the healthy physiological range for sheep. It confirms that Hu sheep have good adaptability to the local environment in this area.

Changes in the count and morphological distribution of red blood cells, white blood cells, and platelets can serve as indicators for assessing whether the physiological functions of an individual livestock or poultry are normal. Red blood cells and hemoglobin ensure tissue respiration, and their count and content are related to factors such as breed, sex, feeding, nutrition, and altitude[7]. Therefore, physiological parameters in the blood can be used as criteria to evaluate the adaptability of livestock and poultry raised in non-native environments. In this study, for Hu sheep raised in the Zizhong area of Sichuan in summer, no significant differences were observed between rams and ewes in hematological parameters such as lymphocyte percentage, total red blood cell count, mean corpuscular volume, mean corpuscular hemoglobin concentration, red blood cell distribution width-coefficient of variation, and total platelet count. Only the total white blood cell count, lymphocyte count, hemoglobin content, hematocrit, and mean corpuscular hemoglobin content were significantly higher in ewes than in rams. Overall, all measured hematological parameters of Hu sheep in this study fell within the normal range for healthy sheep.

The detection of blood biochemical parameters generally includes assessments of liver function, kidney function, blood glucose, blood lipids, and electrolytes. These parameters reflect the metabolic, synthetic, and detoxifying functions of the liver, the filtration and excretory functions of the kidneys, and changes in the body's blood glucose, lipid, and electrolyte levels. In this study, no significant differences were observed between male and female Hu sheep in summer in 11 blood biochemical parameters, including total protein, globulin, and the albumin/globulin ratio. However, ewes exhibited significantly higher values than rams in albumin, cholesterol, alkaline phosphatase, and the urea nitrogen/creatinine ratio, while rams had significantly higher creatinine levels than ewes. For healthy sheep, the 16 blood physiological and biochemical parameters measured in Hu sheep during summer were all within the normal range. Combined with the blood physiological and chemical indicators measured in summer, Hu sheep raised under house-feeding conditions in the Zizhong area are well adapted to the local climatic environment.

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(Continued on page 24)

(Table 2)

Soil type	Area//km^2	Second National Soil Survey		Multipurpose survey		△SOC		Annual change rate
		SOC density kg/m^2	SOC storage Mt	SOC density kg/m^2	SOC storage Mt	Storage//Mt	Change//%	$kg/(m^2 \cdot a)$
Aeolian sandy soil	728	1.23	0.90	1.68	1.23	0.33	36.67	0.025
Cinnamon soil	22 068	1.67	36.87	2.72	60.11	23.24	63.03	0.059
Red clay soil	232	1.75	0.41	2.89	0.67	0.26	63.41	0.062
Alkaline soil	20	1.20	0.02	2.14	0.04	0.02	100.00	0.056
Shajiang black soil	7 388	1.74	12.87	2.86	21.16	8.29	64.41	0.062
Lithic soil	1 940	1.34	2.59	2.50	4.84	2.25	86.87	0.064
Paddy soil	1 416	1.99	2.82	3.89	5.5	2.68	95.04	0.105
Newly accumulated alluvial soil	1 624	1.22	1.97	1.51	2.45	0.48	24.37	0.016
Saline soil	808	1.51	1.22	2.09	1.69	0.47	38.52	0.032
Brown soil	26 704	1.32	35.28	2.07	55.18	19.90	56.41	0.041
Total	158 284	1.43	226.41	2.22	350.65	124.24	54.87	0.044

Conclusions and Discussion

The SOC densities of the three soil layers (0 – 20, 0 – 100, and 0 – 160 cm) in Shandong Province were 2.22, 7.64, and 10.09 kg/m^2, respectively. Compared with the national SOC density, the SOC density of each layer in Shandong was significantly lower. The spatial distribution of topsoil SOC density generally showed a pattern of low values in coastal areas, moderate values in the northwestern plain and eastern hilly regions, and relatively high values in the central and southern mountainous areas.

Using the data from the Second National Soil Survey of Shandong Province in the 1980s and the data from this multipurpose geochemical survey, the "carbon source/sink" effect of the region can be quantitatively and qualitatively estimated. The two surveys were conducted 18 years apart (1985 – 2003). Over the 18 year period, the topsoil SOC content increased from 0.53% to 0.83%, and the storage increased from 226.41 to 350.65 Mt, a net increase of 124.24 Mt. In the storage, the the amount of "carbon source" was 6.76 Mt, and that of "carbon sink" was 131.00 Mt. SOC accumulated in the soil at an average rate of 0.044 $kg/(m^2 \cdot a)$, with the fastest accumulation occurring in paddy soil [0.105 $kg/(m^2 \cdot a)$] and lithosol [0.064 $kg/(m^2 \cdot a)$]. The results of this study provide a new approach for exploring the spatial distribution and variation patterns of soil carbon storage.

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(Continued from page 17)

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