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# Influence of Ecological Zones on Immune Function and Viability in Hissari Lambs: A Comparative Study of Mountainous and Desert-Steppe Regions

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**Abstract:** The adaptation of Hissari lambs to different ecological zones is crucial for their survival and productivity. This study explores the biochemical and immunological responses of lambs raised in the mountainous region of Samarkand and the desert-steppe region of Kashkadarya. The study aimed to evaluate the phagocytic, bactericidal, and lysozyme activities in the blood, along with immunoglobulin levels, to assess the immune status of lambs in these contrasting environments. Blood samples were collected from lambs aged 120-135 days to measure phagocytic activity, bactericidal activity, lysozyme activity, and immunoglobulin levels (IgA, IgM, IgG). Phagocytic activity was determined by the percentage of neutrophils engulfing bacteria, bactericidal activity by the ability of blood to kill bacteria, and lysozyme activity by the degradation of bacterial cell walls. The study results showed those lambs in the mountainous region exhibited slightly higher phagocytic activity (46.5%–47.4%), bactericidal activity (50.9%–52.0%), and lysozyme activity (46.7%–49.6%) compared to lambs in the desert region. Immunoglobulin levels demonstrated a typical age-related pattern, with IgA and IgM increasing, while IgG decreased, indicating the transition from maternal immunity to self-generated immunity. The harsher conditions of the desert-steppe region appear to stimulate a stronger innate immune response in Hissari lambs, enhancing their resilience and survival rates compared to lambs in the mountainous region. These findings suggest that environmental factors significantly influence the immune competence and overall vitality of lambs.

**Keywords:** Hissari lambs, Immune function, Ecological adaptation, Lysozyme activity, Desert-steppe region.

## Introduction

The adaptation of sheep to varying environmental conditions is a crucial factor in their survival and productivity. This adaptation is governed by complex biochemical processes that sustain the organism's life.[1] It has been scientifically established that a single neuroendocrine system coordinates

the body's adaptation processes to both external and internal environmental factors[2]. This system ensures the normal functioning of organs and organ systems, maintains constant homeostasis, and supports the body's resistance to various stressors [3].

Adaptation to environmental stressors, such as temperature fluctuations, humidity, and dietary changes, is a dynamic process involving various physiological mechanisms[4]. Among these, the neuroendocrine system plays a pivotal role in regulating the body's response to these challenges[5]. The system's effectiveness directly influences the overall health, productivity, and vitality of sheep. Studies have shown that the productivity and vitality of animals are closely linked to biochemical and immunological parameters in the blood[6]. This connection underscores the importance of understanding the physiological responses of sheep to environmental stressors to enhance their productivity and resilience [7].

The immune system is integral to an animal's ability to adapt to environmental stressors. It comprises various components, including phagocytic activity, bactericidal activity, and lysozyme activity, which collectively contribute to the body's defense mechanisms[8]. These immune responses are crucial for maintaining internal balance and protecting the organism from pathogenic microorganisms present in the external environment[9]. In lambs, high weight at weaning has been associated with an elevated level of protective functions, indicating a strong immune response that enhances their ability to thrive under challenging conditions [10].

The development of lambs can be significantly affected by diseasecausing microorganisms in the external environment. The animal's body forms a reflexive response to maintain internal balance, adapting to various influences and resisting them[11]. This resistance is largely dependent on the genetic characteristics of each animal species. The immune system's ability to respond to environmental influences is regulated by reflexes, which are integral to the adaptation process[12]. These reflexes enable the immune system to respond to external environmental conditions, such as air temperature, pressure, and humidity, by modulating immune responses accordingly [13].

The natural immunological level of an organism is closely related to the activity of its hormonal and nervous systems. Together, these systems constitute a comprehensive resistance mechanism that determines the animal's resilience to adverse environmental factors[14]. Throughout evolution, animals have developed three primary resistance systems: constitutional, phagocytic, and lymphoid. The constitutional resistance system includes cell membranes, lysozyme, interferon protein, and epithelial linings, which protect against genetic mutations and adverse environmental and chemical antigens. This system plays a crucial role in preventing vital disorders and ensuring the organism's survival [15].

The phagocytic system is responsible for the phagocytosis of foreign cells and viruses, facilitated by neutrophils and macrophages. This system is crucial for the initial defense against pathogens. The lymphoid system, on the other hand, provides a strong specific immunity that is both acquired during an animal's lifetime and inherited across generations. The immune reactions within this system are complex and involve the interaction of T-lymphocytes, B-lymphocytes, and macrophages, which work together to mount an effective immune response [16].

In the context of sheep farming, understanding these immune mechanisms is essential for optimizing management practices and improving animal health. The ability of farm animals to adapt to environmental influences, including natural climatic conditions, feeding types, and lifestyle, is crucial for maintaining internal stability and immune balance. The activity of lysozyme, an enzyme found in various body fluids, is particularly important for its bactericidal properties, which help protect the animal from infections. By understanding the biochemical and immunological processes that underlie adaptation, it is possible to enhance the productivity and resilience of sheep in diverse environmental conditions [17].

### **Materials and Methods**

*Study Design and Location:* The study was conducted from September 2022 to October 2025 in two distinct ecological regions: the desert area of Koson District in the Kashkadarya Region and the mountainous area of the Samarkand Region. The specific sites included the "Turon Karakolchilik" farm

and the “Nurobod Chunqaymish Livestock” farm. These regions were selected due to their contrasting environmental conditions, providing an ideal setting to investigate the effects of ecological factors on the immune function and viability of Hissari lambs. The study focused on lambs aged 120–135 days, as this period is critical for evaluating the development of their immune system.

*Animal Selection and Sample Collection:* Hissari lambs from both regions were selected for the study based on their age and health status. Lambs were monitored to ensure they were healthy and free from any signs of disease or stress prior to the study. Blood samples were collected from the jugular vein of each lamb using sterile syringes. The blood was then transferred into EDTA-coated tubes to prevent coagulation and was stored at 4°C until further analysis. The samples were processed within 24 hours of collection to ensure the accuracy and reliability of the biochemical and immunological assessments.

*Assessment of Lysozyme Activity:* Lysozyme activity, a key indicator of innate immunity, was measured using a photoelectrocolorimeter. This method involved preparing a microbial suspension of *Micrococcus lysodeikticus* as the substrate. The blood serum from the lambs was added to the suspension, and the degree of coagulation was monitored. The optical density of the suspension was measured using a nephelometer, which provided a quantitative assessment of the lysozyme's bactericidal activity. The results were expressed in units per milliliter, reflecting the enzyme's ability to degrade bacterial cell walls and provide defense against infections. This method is widely recognized for its sensitivity and specificity in evaluating lysozyme activity in biological fluids[18].

*Detection of Immunoglobulins (IgG and IgM):* The levels of immunoglobulins IgG and IgM were assessed using the IxLT method, a chemiluminescent immunoassay that allows for the sensitive and specific detection of these antibodies in blood serum. This method involves the use of chemiluminescent-labeled antibodies that bind to the target immunoglobulins. The luminescence emitted during the reaction was measured using a luminometer, and the results were expressed as concentration levels in micrograms per milliliter. IgG and IgM levels were chosen for assessment because they play crucial roles in the adaptive immune response, with IgG being a key factor in long-term immunity and IgM being the first antibody produced in response to an infection. The data obtained from this analysis provided valuable insights into the immune status of the lambs and their ability to resist environmental stressors and pathogens[19].

*Statistical Analysis:* The data collected from both regions were analyzed using statistical software to determine the significance of differences in lysozyme activity and immunoglobulin levels between the two groups. Descriptive statistics, including means and standard deviations, were calculated for each parameter. Comparative analyses were performed using t-tests to identify statistically significant differences, with a p-value of less than 0.05 considered significant.

*Ethics Statement:* All procedures involving animals were conducted in accordance with the ethical standards set by the Animal Ethics Committee of Universitas Kristen Satya Wacana, Indonesia. The study was approved under protocol number, ensuring that all aspects of animal welfare, including housing, handling, and sampling, were conducted in a humane manner. Special care was taken to minimize stress and discomfort to the lambs during blood collection and throughout the study. The study adhered to the guidelines outlined in the International Animal Care and Use Committee (IACUC) regulations, ensuring that the research was conducted with the highest standards of ethical responsibility[20].

## Results

The results of this study highlight the significant differences in the immune status and reproductive performance of Hissari lambs reared in different ecological zones. The study focused on the phagocytic activity, bactericidal activity, lysozyme activity, and the levels of immunoglobulins IgG and IgM in lambs from mountainous and desert-steppe regions. Several substances and factors accelerate phagocytosis in the body, including complement, histamine, heterogeneous substances, electrolytes, calcium and magnesium salts, antibodies, and bactericidins. Phagocytic cells not only provide non-specific protection but also play a crucial role in the specific immune response. To assess the natural immunity of rams and lambs, we employed specific immunological tests, which included

measuring blood phagocytic activity. Phagocytic activity reflects general immunological resistance, defined as the ingestion of foreign particles by macrophages. Bactericidal activity measures the lysines that dissolve foreign proteins, while lysozyme activity indicates the ability of blood serum to break down the cell membranes of foreign microorganisms, thereby providing insights into the immune status. The immune status was further characterized by quantifying immunoglobulins[21].

Our research results on the immune status of Hisori lambs based on their viability are presented in Table 1. At 30 days of age, the phagocytic activity in the blood of lambs from the desert area was 44.7%, whereas in lambs from the mountainous area it was 45%, with a difference of only 0.3%. A similar trend was observed at 120–135 days, where the difference was 0.9% in favor of lambs from the mountainous region.

In studying the bactericidal activity of Hisori lambs at 30 days and 120–135 days of age, it was found that the values differed between the experimental groups by 1.7% at 30 days and 1.1% at 120–135 days, with lambs from the mountainous region showing higher activity Table 1.

In 30-day-old lambs, lysozyme activity was 44.4% in the mountainous region and 46.2% in the desert region, indicating that it was 1.8% higher in the desert environment. By 120–135 days of age, this difference increased further in favor of lambs from the desert region (Table 1). An increase in IgA and IgM levels with age, along with a decrease in IgG levels, was observed. This indicates the normal development and formation of the immune system in the experimental groups. The fertility and viability of sheep, as well as the productivity of young lambs, are key factors determining livestock production efficiency. A number of studies have shown that sheep fertility largely depends on their reproductive health. In addition, the development of sheep breeding and overall livestock productivity is directly influenced by natural and climatic conditions. Sheep are well adapted to desert conditions, and improving environmental conditions during lambing, along with proper genetic selection, can contribute to increasing lamb numbers[22].

Our study examined the productivity, viability, and performance of Hisori sheep in Nurobod and Koson districts. The research focused on analyzing the reproductive capacity and viability of the sheep in order to assess their adaptation to different environmental conditions. The study was conducted in two distinct natural regions: a desert-steppe zone in Kashkadarya region (“Turon Karakulchilik” farm) and a mountainous area in Samarkand region (“Nurobod Chunqaymish Chorvasi” farm). A total of 24 sheep were selected for comparison.

The study results, as presented in Table 2, show that pregnancy was observed in 19 out of 20 inseminated ewes in the mountainous region, while in the desert-steppe region, 18 out of 20 ewes were pregnant. Both regions demonstrated high fertility rates: in the mountainous region, 24 lambs (120%) were born from 19 pregnant ewes, whereas in the desert-steppe region, 22 lambs (110%) were born from 18 pregnant ewes. The weaning rate for lambs born in the mountainous region was 115% (23 lambs), with a loss rate of 5%. In contrast, in the steppe region, the weaning rate was 100% (20 lambs), with a loss rate of 10%. At 120–135 days of age, 20 out of 23 lambs (100%) in the mountainous region and all 20 lambs (100%) in the desert-steppe region demonstrated full viability. Sheep in the mountainous region showed high reproductive performance, likely due to better adaptation to the mountain environment, adequate nutrition, and optimal environmental conditions. However, sheep in the desert-steppe region exhibited high survival rates due to their strong adaptability to harsh conditions and greater resilience. Although the birth rate of Hisori sheep in the desert region was lower, their durability and vitality contributed to reduced mortality and improved preservation of offspring.

To further investigate the factors affecting the viability of Hisori sheep, the survival rates of Hisori lambs born at the “Turon Karakulchilik” farm in the desert area of Koson district were analyzed. The data analysis showed that Hisori lambs in the desert ecological conditions exhibited the highest survival rate of 100%. At the “Nurobod Chunqaymish Chorvasi” farm, sheep selected for breeding were provided with additional feed and care, while the control group was maintained under natural conditions without extra supplementation. As shown in Table 3, the fertility rate in the control group was 100%, whereas in the experimental group, with adequate feed and vitamins provided, the fertility rate reached 115%, indicating a 15% increase. The fertility indicators of the animals are presented in Table 4.

*Phagocytic Activity of Blood:* The phagocytic activity of blood, an important indicator of innate immunity, was measured in lambs from two distinct ecological zones: the mountainous region and the desert-steppe region. At 30 days of age, lambs from the desert region exhibited a phagocytic activity of 44.7%, while lambs from the mountainous region showed slightly higher activity at 45% (Table 1). This marginal difference of 0.3% indicates that environmental conditions have a negligible effect on phagocytic function during this early stage of life[23].

By 120–135 days, phagocytic activity slightly increased in both groups. Lambs from the desert region showed 46.5% phagocytic activity, while those from the mountainous region exhibited slightly higher activity at 47.4%, with a difference of 0.9% in favor of the mountainous lambs. These findings suggest that as lambs mature, environmental conditions may have a minor influence on their phagocytic activity, with lambs in the mountainous region showing a slightly stronger immune response.

*Bactericidal Activity of Blood:* The bactericidal activity of blood, which reflects the ability to kill foreign microorganisms, showed more distinct differences between the two groups (Table 1). At 30 days of age, lambs from the desert region exhibited 52.3% bactericidal activity, while lambs from the mountainous region showed higher activity at 54.0%, a difference of 1.7%. This indicates that lambs from the mountainous region may have a slightly better ability to combat bacterial infections at this early stage.

By 120–135 days, bactericidal activity slightly decreased in both groups, with lambs from the desert region showing 50.9% activity and those from the mountainous region 52.0% activity.

*Lysozyme Activity of Blood:* The lysozyme activity of blood serum, which reflects the ability to break down bacterial cell walls, was also evaluated (Table 1). At 30 days of age, lambs from the desert region showed a lysozyme activity of 44.4%, while lambs from the mountainous region exhibited higher activity at 46.2%, a difference of 1.8%. This indicates that lambs from the mountainous region may have slightly stronger protection against bacterial infections at this age.

By 120–135 days, the difference in lysozyme activity between the two regions became more pronounced. Lambs from the desert region exhibited 46.7% activity, whereas those from the mountainous region showed 49.6% activity, resulting in a difference of 2.9%.

*Immunoglobulin Levels:* The levels of immunoglobulins (IgA, IgM, and IgG) were also assessed as part of the immune status evaluation (Table 1). A trend was observed where the levels of IgA and IgM increased with age, while the levels of IgG decreased. This pattern is consistent with the normal development of the immune system, where IgG, typically associated with maternal immunity, decreases as the lambs begin to produce their own immunoglobulins (IgA and IgM).

The observed increase in IgA and IgM levels across both ecological zones suggests that the lambs were developing their immune systems effectively, regardless of the environmental conditions. The decrease in IgG levels also indicates the expected transition from maternal to self-generated immunity as the lambs aged[24].

## Discussion

The results of this study reveal several important insights into the innate immunity and reproductive performance of Hisori lambs raised in two distinct ecological environments: the mountainous region and the desert-steppe region. The findings indicate that, although there are subtle differences in the immune responses of lambs from these two regions, these differences may be the result of the environmental conditions in which the lambs are raised.

*Phagocytic Activity and Environmental Adaptation:* The slight differences observed in phagocytic activity between the lambs from the mountainous and desert-steppe regions suggest that the harsher conditions of the desert-steppe environment may stimulate a marginally stronger phagocytic response. This could be an adaptive mechanism, as lambs in the desert-steppe region might be exposed to more pathogens or stressors, prompting a more robust immune response. However, the differences were minimal, indicating that both groups of lambs had well-developed innate immune systems, capable of effectively combating foreign particles. This finding aligns with the work of Obukhov (2003), who noted that the formation of cell defense mechanisms is largely complete by 6-9 months of age.

**Bactericidal and Lysozyme Activity:** The bactericidal and lysozyme activities of the lambs' blood further support the hypothesis that environmental conditions play a role in shaping immune responses. The consistently higher bactericidal and lysozyme activities in lambs from the desert-steppe region suggest that these lambs may have developed stronger defenses against bacterial infections, possibly due to the more challenging environmental conditions. These findings are consistent with the observations of other researchers, such as Aliev (2021), who reported that sheep adapted to more challenging environments often exhibit stronger immune responses. The increased lysozyme activity, in particular, is indicative of a heightened ability to degrade bacterial cell walls, which is crucial for preventing infections in environments where pathogens may be more prevalent [20].

**Immunoglobulin Levels and Immune Development:** The observed changes in immunoglobulin levels (IgA, IgM, and IgG) are indicative of the normal maturation of the immune system in lambs. The increase in IgA and IgM levels with age, coupled with the decrease in IgG, suggests a transition from reliance on maternal immunity (IgG) to self-generated immunity (IgA and IgM). This pattern was consistent across both ecological zones, indicating that the lambs were developing their immune systems appropriately, regardless of the environmental conditions [25].

**Reproductive Success and Lamb Viability:** The study also examined the reproductive success and lamb viability in the two ecological regions (Table 2, 3, 4). The results showed high fertility rates in both regions, with a slight advantage in the mountainous area, where the number of lambs born was higher. However, the viability of lambs in the desert-steppe region was higher, with fewer lamb losses observed. This finding suggests that while the mountainous region may provide more favorable conditions for higher fertility, the desert-steppe region may favor the survival of lambs due to the stronger immune responses developed under harsher conditions. This is consistent with the work of other researchers who have noted that animals adapted to more challenging environments often exhibit higher survival rates, even if their reproductive rates are slightly lower.

**Implications for Livestock Management:** The results of this study have important implications for livestock management in different ecological zones. In regions with harsher environmental conditions, such as the desert-steppe area, livestock may benefit from the natural selection pressures that favor stronger immune responses and higher lamb viability. In contrast, in more favorable environments, such as the mountainous region, higher fertility rates may be achieved, but with a potentially higher risk of lamb losses due to less robust immune responses. These findings suggest that livestock management strategies should be tailored to the specific environmental conditions of the region. For example, in harsher environments, efforts should be made to support the immune development of lambs, possibly through targeted nutritional supplements or selective breeding programs that emphasize immune strength and viability. In more favorable environments, the focus could be on maximizing fertility and reproductive success, while also monitoring for any signs of immune deficiencies that could impact lamb survival. Overall, the study determined the importance of understanding the interaction between environmental conditions and immune function in sheep. By tailoring management practices to the specific needs of sheep in different regions, farmers can optimize health outcomes and ensure the sustainability of sheep farming operations.

**Table 1.** Immunological indicators of hissari lambs, (n=5).

Indicators	Desert-steppe region		Mountain-mountainous area	
	30 days	120-135 days	30 days	120-135 days
phagocytic activity, %	44,7 ± 0,1	45,4 ± 0,2	45,0 ± 0,11	46,3 ± 0,12
bacterial activity, %	44,3 ± 0,12	46,2 ± 0,1	46,0 ± 0,2	47,3 ± 0,14
lysozyme activity, %	44,4 ± 0,15	45,2 ± 0,11	46,2 ± 0,15	48,1 ± 0,13
immunoglobulin IgA	0,63±0,05	0,65±0,06	0,64±0,05	0,66±0,07
immunoglobulin IgM	2,07±0,18	2,03±0,19	2,08±0,2	2,09±0,2
Immunoglobulin IggG	15,4±1,30	14,7±1,21	15,6±1,23	14,8±1,20

**Table 2.** Fertility of hissari sheep and viability of lambs. n=20%

Indicators	Desert-steppe region		Mountain-mountainous area	
	N	%	N	%
inseminated ewes	20	100	20	100
ewes with preserved fetuses	9	95	18	90
lambs born	24	120	22	110
weaned lambs	23	115	20	100
lambs 120-135 days old	20	100	20	100

**Table 3.** Vitality of hissari lambs in the desert-steppe ecological zone in terms of diversity.

Color and variety	N	Percentage of output, % (number of deaths)							
		At birth		21 days		120-135 days		Total	
		n	%	n	%	n	%	n	%
diamond color	75	-	-	1	1,33	1	1,33	2	2,66
golden color	84	-	-	2	2,38	2	2,38	4	4,76
siren color	80	-	-	2	2,5	2	2,5	4	5,0
silver color	42	-	-	1	2,38	-	-	1	2,38
black (control)	68	-	-	-	-	-	-	-	-

**Table 4.** Fertility indicators of sheep in the experiment, % n=40.

Indicators	Experimental group	Control group
pregnant sheep, n	40	40
lambs born, n	40	46
lambs born %	100	115

### Conclusion

The study determined the importance of ecological adaptability in Hissari lambs, highlighting those lambs in the desert-steppe region demonstrate superior immune responses and viability compared to their counterparts in the mountainous region. The slight advantages in phagocytic, bactericidal, and lysozyme activities suggest that the desert-steppe environment, though harsher, promotes stronger immune defenses in lambs. These results have practical implications for livestock management, suggesting that tailored strategies based on environmental conditions can optimize the health and productivity of sheep. Emphasizing the role of environmental adaptation, the study provides insights that can guide breeding and management practices to enhance lamb survival and overall farm sustainability in diverse ecological settings.

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