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

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Abstract

Background: The adaptation of Sur Karakol 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. Methods: 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. Results: The study found that lambs in the desert-steppe 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 those in the mountainous region. Immunoglobulin levels showed a typical pattern of increasing IgA and IgM with age, while IgG decreased, indicating a normal transition from maternal to self-generated immunity. Conclusion: The harsher conditions of the desert-steppe region appear to stimulate a stronger innate immune response in Sur Karakol 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: Sur Karakol lambs, Immune function, Ecological adaptation, Lysozyme activity, Desert-steppe region

Significance | This study revealed the critical role of ecological adaptation in enhancing immune function and lamb viability in diverse environments.

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1. 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. It has been scientifically established that a single neuroendocrine system coordinates the body's adaptation processes to both external and internal environmental factors. This system ensures the normal functioning of organs and organ systems, maintains constant homeostasis, and supports the body's resistance to various stressors (Petrov, 1978; Petrov, 1982; Smith, 2005; Thompson et al., 2010).

Adaptation to environmental stressors, such as temperature

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fluctuations, humidity, and dietary changes, is a dynamic process involving various physiological mechanisms. Among these, the neuroendocrine system plays a pivotal role in regulating the body's response to these challenges. 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. This connection underscores the importance of understanding the physiological responses of sheep to environmental stressors to enhance their productivity and resilience (Aliyev, 2021; Sazonova, 2013; Ismailov et al., 2022; Ivanov & Lebedev, 2015; White & Brown, 2017).

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. These immune responses are crucial for maintaining internal balance and protecting the organism from pathogenic microorganisms present in the external environment. 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 (Ismailov et al., 2023; Sazonova, 2016; Timoshenko, 2014; Vakhrameev et al., 2018).

The development of lambs can be significantly affected by disease-causing microorganisms in the external environment. The animal's body forms a reflexive response to maintain internal balance, adapting to various influences and resisting them. 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. These reflexes enable the immune system to respond to external environmental conditions, such as air temperature, pressure, and humidity, by modulating immune responses accordingly (Obukhov, 2003; Bate & Hacher, 1982; Martinez & Robertson, 2009; Zhang et al., 2021).

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. 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 (Loke & King, 1995; Mukhitdinov et al., 2020; Timashev & Selkin, 1975; Reynolds & Parker, 2016; Wu et al., 2019).

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 (Efanova & Saiduldin, 2004; Kryshstop, 2002; Anderson et al., 2013; Jacobs & Hooper, 2017).

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 (Lezhnina et al., 2019; Sazonova, 2016; Gusev & Kozlova, 2018; Makarova et al., 2022).

2. Materials and Methods

2.1 Study Design and Location

The study was conducted from October 2022 to March 2023 in two distinct ecological regions: the desert area of the Koson District in the Kashkadarya Region and the mountainous area of the Samarkand Region. The specific sites included the "Turon Karakolchilik" farm and the "Hasan-Zukhra Mountain Cattle" farm. These regions were selected due to their contrasting environmental conditions, which provided an ideal setting to investigate the effects of ecological factors on the immune function and viability of Sur Karakol lambs. The study focused on lambs aged 120-135 days, a critical period for evaluating the development of their immune systems.

2.2 Animal Selection and Sample Collection

Sur Karakol 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.

2.3 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.

2.4 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.

2.5 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.

2.6 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 [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.

3. Results

The results of this study highlight the significant differences in the immune status and reproductive performance of Sur Karakol 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.

Obukhov M.N. noted in his studies that the formation of cell defense mechanisms is completed by 6-9 months, while bactericidal and lysozyme activities are fully developed by 3-5 months .

The results of our research on the immune status of Sur Karakol lambs based on their viability are summarized in Table 1. At 30 days, the activity of phagocytes in the blood of lambs from the mountainous area was 44.7%, compared to 45% in lambs from the desert zone, 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 desert-steppe region.

In studying the bactericidal activity of Bukhara Suri lambs aged 30 and 120-135 days, 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 in the desert-steppe region showing superior activity (Table 1).

Lysozyme activity of 30-day-old lambs was 44.4% in the mountainous area and 46.2% in the desert zone, demonstrating a 1.8% higher activity in the desert ecological zone. By the 120-135 day interval, this difference increased to 2.9% in favor of the lambs in the desert region (Table 1). An increasing trend in IgA and IgM levels with age, alongside a decrease in IgG, was observed, indicating a normal progression in the formation of immune status among the experimental groups.

The fertility and viability of Sur Karakol sheep, as well as the productivity of young lambs, primarily determine livestock

productivity. Several studies have shown that sheep fertility significantly depends on the reproductive health of the ewes. Additionally, the development of cattle breeding and animal breeding qualities are directly influenced by natural and climatic conditions. Karakol sheep are well-adapted to desert conditions, and improved conditions during lambing periods, combined with genetic factors, can increase the number of lambs.

Our research investigated the fertility, viability, and productivity of Karakol sheep belonging to the Karakalpak Suri breed from the Nurabad district and the Bukhara Suri breed from the Koson district. The study focused on the adaptation of lambs to different environmental conditions by analyzing their reproductive capacity and viability. This was conducted in two different natural areas: a desert-steppe area in the Kashkadarya region ("Turon Karakolchilik" farm) and a mountainous area in the Samarkand region ("Hasan-Zukhra Mountain Cattle" farm), with a total of 20 ewes 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 and in 18 out of 20 in the desert-steppe region. Both areas showed high fertility rates: 24 lambs (120%) were born from 19 pregnant ewes in the mountainous area, while 22 lambs (110%) were born from 18 pregnant ewes in the desert-steppe area. The weaning rate for lambs born in the mountainous area 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, 20 out of 23 lambs (100%) in the mountainous area and all 20 lambs (100%) in the desert-steppe area showed full viability.

High reproductive qualities were observed in sheep in the mountainous region, likely due to better adaptation to the mountain environment, adequate nutrition, and optimal environmental conditions. However, sheep in the desert-steppe area exhibited a higher survival rate due to their strong adaptability to harsher conditions and greater endurance. While the Sur Karakol sheep in the desert showed lower birth rates, their durability and vitality ensured lower mortality and better preservation of offspring. Conversely, Sur Karakol sheep in the mountainous region, despite their high productivity and multiple births, had lower lamb viability under adverse conditions.

To further understand the factors influencing Karakol sheep viability, we examined the survival rates of lambs of different colors born on the "Turon Karakolchilik" farm in the desert region of Koson district. The survival rates of lambs with a high blood content of biologically active substances and leukocytes from birth until weaning were calculated. The data analysis indicated that lambs of siren and golden color had lower viability rates of 95% and 95.24%, respectively, compared to silvery Sur lambs at 97.62%. Black Karakol lambs showed the highest viability at 100%.

Sheep left for breeding at the "Hasan-Zukhra Mountain Livestock" farm were provided additional feed and care, while those in the control group were maintained in natural conditions without extra feed. As shown in Table 3, the fertility rate was 100% in the control group, while the experimental group achieved a fertility rate of 115%, demonstrating a 15% increase when provided with sufficient nutrition and vitamins under favorable conditions. The indicators of animal fertility are presented in Table 4

3.1 Phagocytic Activity of Blood

The phagocytic activity of blood, an essential marker of innate immunity, was measured in lambs from two distinct ecological zones: the mountainous area and the desert-steppe region. At 30 days of age, the phagocytic activity in lambs from the mountainous area was recorded at 44.7%, while lambs from the desert-steppe region exhibited slightly higher activity at 45% (Table 1). This marginal difference of 0.3% suggests a negligible impact of the environmental conditions on the phagocytic function at this early stage of life.

By 120-135 days, the phagocytic activity in both groups showed a slight increase. Lambs from the mountainous area exhibited a phagocytic activity of 46.5%, whereas lambs from the desert-steppe region demonstrated a slightly higher activity of 47.4%, with a difference of 0.9% in favor of the desert-steppe lambs. These findings indicate that as lambs mature, their phagocytic activity may be influenced by the environmental conditions, albeit slightly, with those in the harsher desert-steppe environment showing a modestly enhanced immune response.

3.2 Bactericidal Activity of Blood

The bactericidal activity of blood, reflecting the ability to kill foreign microorganisms, showed more distinct differences between the two groups (Table 1). At 30 days, lambs from the mountainous area exhibited a bactericidal activity of 52.3%, while lambs from the desert-steppe region showed a higher activity of 54.0%, indicating a difference of 1.7%. This suggests that lambs from the desert-steppe region may have a slightly better ability to combat bacterial infections at this early stage.

By 120-135 days, the bactericidal activity in both groups showed a slight decrease, with lambs from the mountainous area having an activity of 50.9% and those from the desert-steppe region having 52.0%. The difference of 1.1% still favored the desert-steppe lambs, reinforcing the notion that the harsher environmental conditions might contribute to a stronger innate immune response.

3.3 Lysozyme Activity of Blood

Lysozyme activity, indicative of the ability of the blood serum to break down bacterial cell walls, was also evaluated (Table 1). At 30 days, lambs from the mountainous area exhibited a lysozyme activity of 44.4%, while those from the desert-steppe region had a higher activity of 46.2%, showing a difference of 1.8%. This suggests

that lambs in the desert-steppe region may have a slightly more robust defense 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 mountainous area had an activity of 46.7%, whereas those from the desert-steppe region showed an activity of 49.6%, resulting in a difference of 2.9%. This finding further supports the idea that the harsher environmental conditions of the desert-steppe region may contribute to a stronger innate immune response.

3.4 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.

4. Discussion

The results of this study reveal several key insights into the natural immunity and reproductive success of Sur Karakol lambs reared in two distinct ecological environments: the mountainous region and the desert-steppe region. The findings suggest that while there are subtle differences in the immune responses of lambs from these two regions, these differences are likely a result of the environmental conditions in which the lambs are raised (Ismailov et al., 2022; Sazonova, 2013).

4.1 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.

4.2 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 (Mukhitdinov et al., 2020; Sazonova, 2016). 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 (Efimova & Saiduldin, 2004).

4.3 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 (Pirogov, 1978, 1982).

4.4 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 (Timashev & Selkin, 1975). 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 (Bate & Hacher, 1982; Loke & King, 1995).

4.5 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 (Ismoilov et al., 2023). 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

Table 1. Immunological indicators of sur karakol lambs, (n=5)

Indicators	Mountain-mountainous area		Desert-steppe region	
day(s)	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
immunoglobin IgA	0,63±0,05	0,65±0,06	0,64±0,05	0,66±0,07
immunoglobin IgM	2,07±0,18	2,03±0,19	2,08±0,2	2,09±0,2
Immunoglobin IggG	15,4±1,30	14,7±1,21	15,6±1,23	14,8±1,20

Table 2. Fertility of sur karakol sheep and viability of lambs. n=20% (2022-2023)

Indicators	Mountain-mountainous area		Desert-steppe region	
	N	%	N	%
inseminated ewes	20	100	20	100
ewes with preserved fetuses	19	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 sur karakol 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	-	-	-	-	-	-	-	-

explanation; n-number of pregnant sheep, (in favorable conditions, when there is enough feed)

Table 4. Fertility indicators of sheep in the experiment, % n=40 (2023)

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

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 (Leshnina et al., 2019).

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.

5. Conclusion

The study determined the importance of ecological adaptability in Sur Karakol 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.

Author contributions

M.S.M. prepared the original draft of the manuscript. D.D.A., I.K.T., O.B.S., and A.O.S.U. contributed to the review and editing of the manuscript.

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Competing financial interests

The authors have no conflict of interest.

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