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# Nodular Typhlitis Associated with *Heterakis* spp. in Golden Pheasants (Chrysolophus pictus): A Pathological and Immunohistochemical Investigation

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## ABSTRACT

This report details nodular typhlitis associated with *Heterakis* spp. in golden pheasants (Chrysolophus pictus) focusing on clinical and pathological findings. Necropsies found hemorrhagic ceca filled with multifocal white nodules. Histopathological analysis has shown necrotic foci, inflammatory infiltrations, and parasite fragments in the submucosa and tunica muscularis, and perivascular spindle-cell proliferation assumed a whirling pattern consistent with perivascular origin. Masson's trichrome staining revealed only limited peripheral collagen, whereas the core nodules consisted of mesenchymal spindle cells with vimentin and α-smooth muscle actin (α-SMA) positivity, along with focal S-100 reactivity in some sections and uniform desmin negativity. While leiomyomas have been reported in *Heterakis* infections, the immunophenotypic profile—characterized by diffuse vimentin and SMA, occasional S-100 positivity, and absence of desmin—suggests a lesion with perivascular or undifferentiated mesenchymal features rather than a classical smooth muscle neoplasm or neurogenic tumor. Our observations thus expand the spectrum of pathological outcomes following chronic *Heterakis* infection in pheasants and underscore the value of immunohistochemistry in characterizing such spindle-cell lesions.

## 1. INTRODUCTION

*Heterakis* species are members of the Ascaridida order, a large group of nematodes with direct life cycles that primarily inhabit the gastrointestinal tracts of chickens, pheasants, turkeys, and wild birds (Ayeni et al. 1983; Draycott et al. 2000; Fedynich, 2008; Menezes et al. 2003; Millán et al. 2004; Norton et al. 1999; Rizzoli et al. 1999; Tompkins et al. 2002). These small (5.5–31 mm), whitish-tan nematodes typically reside in the cecum of their host (Cram 1927; Madsen 1941; Maplestone 1932). There are three clinically significant species in poultry—*H. gallinarum, H. dispar,* and *H. isolonche* (Soulsby 1982). Among these, *H. isolonche* is more commonly linked to severe nodular or verrucous typhlitis, characterized by granulomatous and even neoplastic nodules in the cecal wall and submucosa. Although *H. gallinarum* was traditionally viewed as less pathogenic, recent reports document that this species, too, can provoke severe nodular typhlitis with granulomatous cecal lesions in domestic chickens (Menezes et al. 2003).

Nodular typhlitis is previously described most commonly in pheasants, with multiple nodular lesions in the cecal wall resulting in significant morbidity and mortality (Menezes et al. 2003). Infections with heavy burdens of *H. isolonche* in golden pheasants (*Chrysolophus pictus*) have been associated with diarrhea, emaciation, and mortality (JPC 2024). Grossly, the ceca are thickened and have many firm, small raised nodules (usually ≥1–2 mm), giving a prominent "cobblestone" appearance of the mucosal surface. In severe cases, widespread cecal affection may lead to intestinal intussusception (Menezes et al. 2003). Traditionally, these nodules have been considered nothing more than granulomatous or fibroplastic responses to *Heterakis* larvae. However, they often contain interwoven bundles and whirls of spindle cells consistent with a possible sarcomatous nature. Additionally, under similar infections, not all galliform birds (e.g., quail or grouse) form similar nodules sharing typical co-pathological response, suggesting a species-genus-confined pathologic response (JPC 2024).

Over time, a consensus emerged that many of these lesions represent true neoplasia rather than purely inflammatory changes. Benign smooth muscle tumors (leiomyomas) were identified in heavily parasitized pheasant ceca (Menezes et al. 2003), and Helmboldt and Wyand (Helmboldt & Wyand, 1972) documented "neoplastic nodules" in golden pheasants, categorizing them as leiomyomas induced by *Heterakis* infection—occasionally even when only *H. gallinarum* was present. Subsequent investigations demonstrated that *H. isolonche* as well as *H. gallinarum* can induce the development of these innocuous lesions, typically exhibiting little mitotic activity or invasion (Menezes et al. 2003). By the late 20th century, chronic parasitic typhlitis in pheasants had been widely acknowledged as leading to uncontrolled cellular proliferation, therefore serving as a prime example of parasitic neoplasia (Jones et al. 1997).

The pheasant parasite-associated neoplasia parallels that reported from other species, not the least of which is *Spirocerca lupi* infections in canids, where granulomas of the esophagus develop into malignant sarcomas (Boros et al. 2020). In pheasants, *Heterakis* infection usually causes cecal leiomyomas or leiomyosarcomas through chronic inflammation and tissue damage (Boros et al. 2020). However, a

population of infected pheasants does not go on to develop tumorous lesions, indicating that host determinants, such as immune response or genetic susceptibility, may contribute (Menezes et al. 2003). The association of *Heterakis* infection with cecal nodular tumors highlights nodular typhlitis as a classic example of inflammation-driven neoplasia in avian pathology.

This study aimed to investigate nodular typhlitis attributed to *Heterakis* species in a pheasant flock with high mortality and to characterize the resultant cecal lesions through histopathological and immunohistochemical analyses.

## 2. MATERIALS AND METHODS

### 2.1. Animals

The study material comprised 22 golden pheasants (*Chrysolophus pictus*) housed at Antalya Zoo. Two adult pheasants (approximately 1.5 kg body weight), which were among those that succumbed to the disease, were submitted for necropsy. No antemortem fecal examinations were recorded.

### 2.2. Histopathology

Formalin-fixed tissues were processed by routine methods and embedded in paraffin. Sections (4 µm) were cut and stained with hematoxylin and eosin (H&E) for light microscopic examination. Masson's trichrome stain (#04-010802; Bio-Optica, Milan, Italy) was used primarily to distinguish collagen (stained blue) from muscle-like tissue in the nodular lesions. Additionally, sections were closely examined for the parasites or parasite eggs within the lesions.

### 2.3. Immunohistochemistry (IHC)

An IHC panel was applied to the cecal nodular lesions to determine the phenotype of the proliferating spindle cells. After antigen retrieval, serial sections were immunolabeled with the following primary antibodies: vimentin [a broad mesenchymal cell marker (M7020, Dako; 1:200 dilution)], α-smooth muscle actin [α-SMA, marker of smooth muscle and myofibroblastic cells (M0851, Dako; 1:100 dilution)], desmin [marker of differentiated smooth and skeletal muscle (M0760, Dako; 1:100 dilution)], and S-100 protein [(marker of neural crest-derived cells such as Schwann cells (Z0311, Dako; 1:400 dilution)]. A standard streptavidin-biotin-peroxidase complex technique was used with appropriate positive and negative controls for each marker. The antibody reactions were visualized with 3,3'-diaminobenzidine (DAB) chromogen and hematoxylin counterstain.

No molecular assays were conducted in this case. However, morphological identification of any parasites in tissue was attempted using published criteria for *Heterakis* species. The few adult nematodes collected from the cecal content were preserved in 70% ethanol and later examined microscopically to aid in species identification based on morphological features (such as the presence of cecal ridges, and male spicule length, which differentiate *H. isolonche* from *H. gallinarum*). Because only a limited number of worms were present and they were female (lacking distinctive male features), definitive species identification was impossible; however, *Heterakis* sp. was confirmed.

# 3. RESULTS

## 3.1. Clinical Observations and Outcome

Of the 22 pheasants, clinical signs included white diarrhea, cachexia, weakness, and lethargy. Despite initial treatment with Sulphamezathine and B vitamins, followed by Amoxicillin and B vitamins, the flock experienced a mortality rate of 2–3 birds per day, ultimately leaving only three survivors. No antemortem fecal examinations were recorded. The high mortality despite antibiotic and supportive therapy underscored the severity of the underlying parasitic infection, suggesting that targeted anthelmintic intervention might have been crucial for reducing losses.

## 3.1. Gross Findings

The primary lesion was confined to the ceca, which were carpeted with multifocal to coalescing nodules (Fig. 1). Each nodule was firm and pale, ranging from pinpoint to about 0.5 cm in the largest dimension. The cecal walls were diffusely thickened and less pliable due to the dense nodules within them. The mucosal surface had a rough, nodular contour, while externally the serosa also appeared undulant due to transmural nodular expansion. No significant luminal obstruction was noted when incising the ceca, but the number of nodules indicated a severe chronic process. Several cross-sections of slender whitish nematodes (~1–1.5 cm long) were found in the cecal content. No other gross abnormalities were identified in the bird; the liver, spleen, and intestine (apart from the ceca) appeared grossly normal, and there were no ascites or peritonitis.

**Fig. 1.** Nodular lesions observed in the ceca of two pheasants (arrows).

## 3.3. Histopathologic Findings

Microscopically, the cecal nodules consisted of proliferative spindle cell tumors centered in the submucosa and muscularis (Fig. 2A-F). These expansile nodular masses disrupted the normal architecture of the cecal wall. The neoplastic cells were fusiform with elongate, blunt-ended nuclei and moderate pale eosinophilic cytoplasm. They were arranged in interwoven fascicles and whorled patterns, often concentrically around small blood vessels (perivascular whirling). The cell density was high in the nodules, but cellular atypia was low: the nuclei were fairly uniform with only mild to moderate pleomorphism, and mitotic figures were rare (averaging <1 per high-power field). No evidence of overt malignancy, such as invasive growth into adjacent tissues or metastatic spread to other organs, was observed. The boundaries of the nodules were generally pushing/compressive rather than infiltrative. Masson's trichrome staining showed minimal to moderate collagen at the edges of the nodules. The bulk of each nodule consisted of spindle cells that did not stain strongly for collagen, suggesting a primarily muscle-like or myofibroblastic composition (Fig. 2G, H).

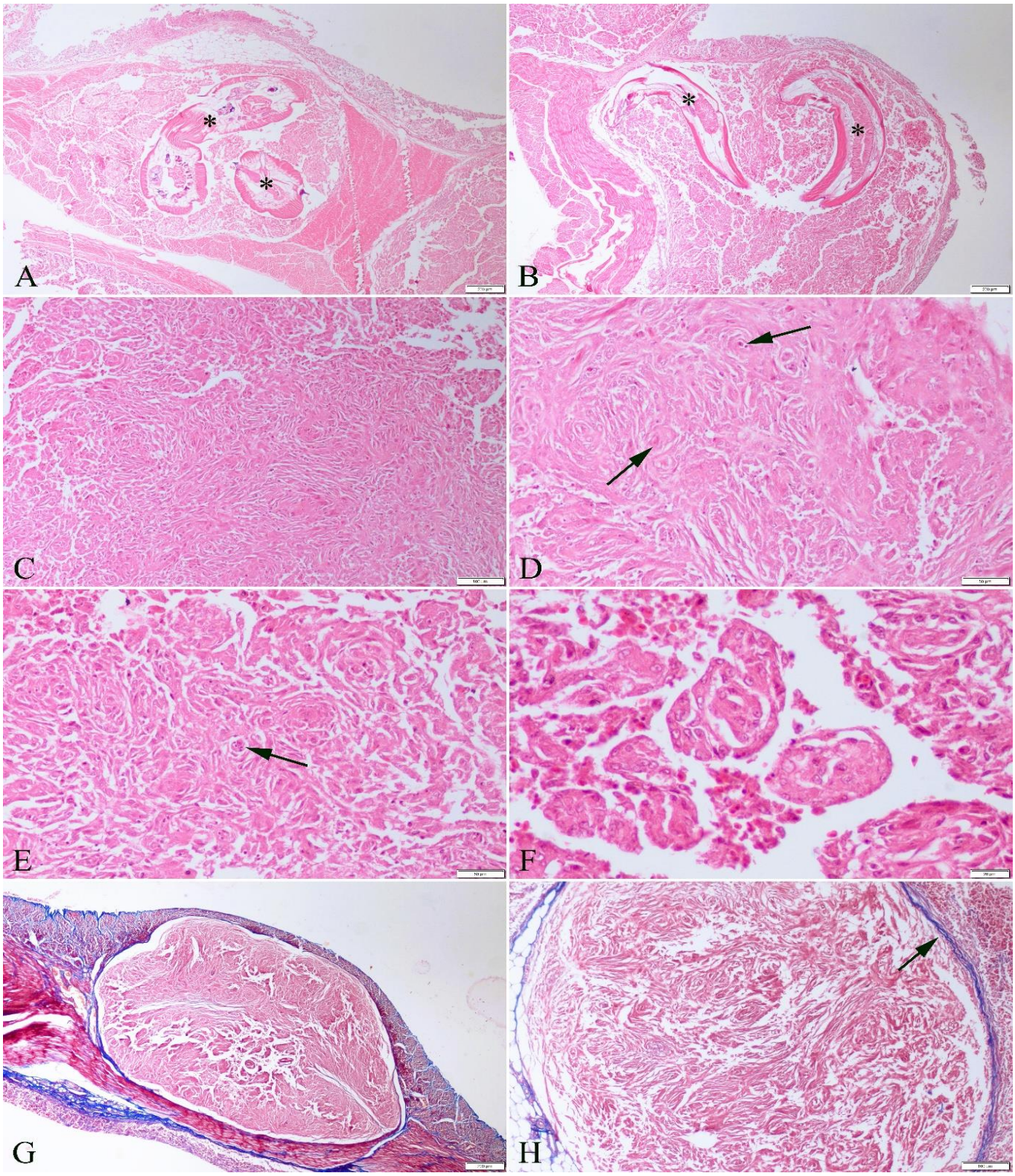


**Fig. 2.** Parasite cross-sections surrounded by neoplastic formations in microscopic sections of the cecum (stars) (A, B), H&E; Neoplastic cells exhibiting a whorled proliferation pattern around blood vessels (arrows) (C-E) with mild to moderate pleomorphism (F), H&E; Collagen staining observed around, but not within, the neoplastic areas (arrows) (G, H), Masson's Trichrome. Scale bars: 200 µm (A, B, G); 100 µm (H, C); 50 µm (D, E); 20 µm (F).

Interestingly, within some nodules there were central areas of necrosis containing remnants of nematode larvae. Affected nodules often showed a granulomatous reaction around these parasite remnants: multinucleated giant cells, epithelioid macrophages, and lymphoplasmacytic infiltrates were present at the core of such lesions. Cross-sections of a nematode with a thick cuticle, pseudocoelom, muscle layers, and an intestine were identified in a few sections, consistent with an immature *Heterakis* spp. worm. In nodules where parasite sections were found, the surrounding spindle cell proliferation appeared particularly well-developed, suggesting the parasite as a stimulus. Some nodules lacked any visible parasite, consisting purely of spindle cells and fibrous stroma – these may have been older lesions where the inciting larva died and was resorbed. No clusters of protozoal parasites (e.g., Histomonas) were seen in the cecal tissue. The other examined tissues (including liver and spleen) had no significant lesions, apart from mild reactive changes.

### 3.4. Immunohistochemistry Results

Immunohistochemistry revealed that the spindle cells exhibited diffuse cytoplasmic vimentin labeling, consistent with a mesenchymal phenotype. α-SMA reactivity was also prominent, suggesting myofibroblastic or pericytic differentiation. Desmin was entirely negative, ruling out a well-differentiated smooth muscle tumor (leiomyoma). S-100 showed sparse, patchy immunopositivity in a few scattered cells, potentially representing entrapped nerve elements or minimal neural differentiation; the majority of the neoplastic spindle cells were S-100–negative. This prominent α-SMA and vimentin reactivity coupled with weak and partial S-100 positivity and desmin negativity collectively points to a pericytic (perivascular) or myofibroblastic proliferation rather than a classic leiomyoma or neurofibroma. The perivascular whorling pattern further supports a perivascular wall tumor (PWT) origin. Figure 3 illustrates the immunohistochemical features observed.

### 3.5. Ancillary Findings

Given the histological evidence of larvae embedded in the cecal wall, it is likely that the *Heterakis* infection (regardless of species) was the inciting factor for tumor formation. No evidence of other infectious agents was found in association with the lesions. Additionally, a parasitological fecal examination of the intestinal content was performed using the Fülleborn flotation method, revealing the presence of *Heterakis* spp. eggs (Fig. 4). Therefore, the final diagnosis was nodular typhlitis with parasite-associated PWT of the cecum in a golden pheasant with *Heterakis* spp. identified as the etiological agent in the lesions.

## 4. DISCUSSION

*Heterakis gallinarum* has long been identified as a prevalent nematode of the ring-necked pheasant in the USA (Gilbertson & Hugghins, 1964; Olsen & Braun, 1980; Pence et al. 1980), European countries (Draycott et al. 2000; Madsen 1941), and Türkiye (Gürler et al. 2012). There is limited knowledge regarding the pathological impact of *Heterakis* in wild birds, but poultry and pheasants—particularly the latter—are known to be highly susceptible (Fedynich 2008). While H. gallinarum has been implicated in clinical signs ranging from inflammation to tumor-like lesions, H. isolonche is typically associated with the most severe clinical outcomes (Halajian et al. 2013).

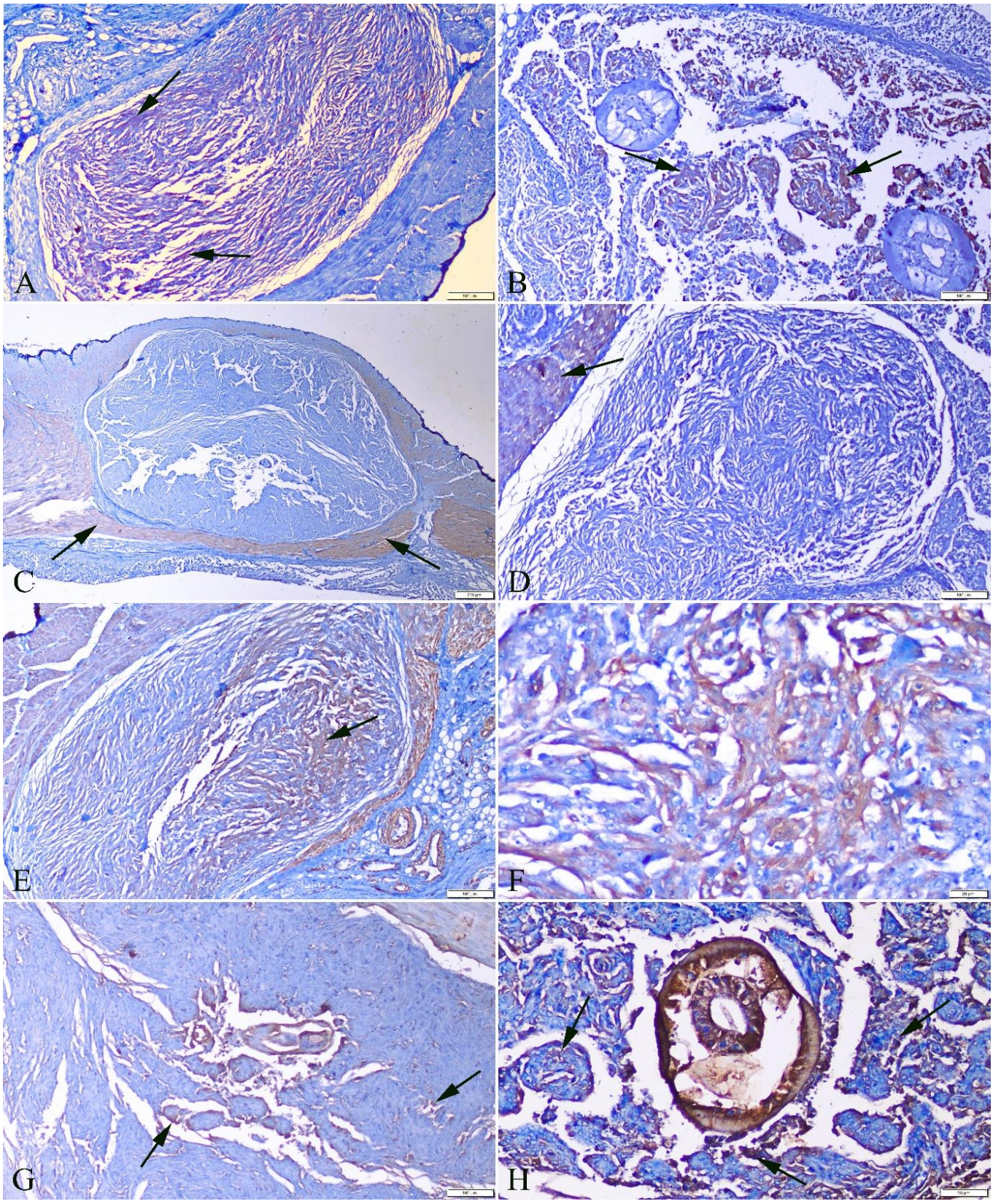


**Fig. 3.** Widespread vimentin positivity in neoplastic areas (A, B); desmin staining restricted to the muscle layer outside neoplastic regions (C, D); diffuse α-SMA expression in tumor cells (E, F); and partial S100 staining (G, H). Arrows indicate positive staining areas. DAB counterstain. Scale bars: 200 µm (C); 100 µm (A, B, D, E, G); 50 µm (H); 20 µm (F).

In this case study, definitive species identification was impossible because of the limited available worm material; however, the presence of larvae within lesions strongly implicates *Heterakis* spp. as the etiological agent.

**Fig. 4.** Microscopic view of a *Heterakis* spp. egg using the Fülleborn flotation method. Scale bar: 20 µm.

Numerous reports have documented nodular typhlitis in pheasants caused by both *H. gallinarum* (Menezes et al. 2003) and *H. isolonche* (Balaguer et al. 1992; Callinan 1987; Griner et al. 1977; Schwartz 1924). This disease is characterized by inflammatory, granulomatous, or even neoplastic nodules in the cecal wall—especially the submucosa—ranging from 1 to 8 mm in diameter and varying in color from pale white or pink to dark brown (Griner et al. 1977; Menezes et al. 2003). After initial nodule development, the host mounts a vigorous immune response mediated by lymphocytes, macrophages, and fibroblasts surrounding the parasites (Balaguer et al. 1992; Callinan 1987). Later on, degenerate worms are surrounded by older nodules containing epithelioid cells, plasma cells, and giant cells (Balaguer et al. 1992). Our findings also showed similar nodular lesions with occasional necrotic foci and acute inflammatory reactions, but the predominant lesions were proliferative, tumor-like spindle-cell proliferations with occasional inflammatory cells, consistent with a neoplastic process rather than a purely inflammatory nature.

The primarily proliferative mesenchymal cell population seen in nodular typhlitis has been described using a variety of terminologies, including the classic "nodular typhlitis" (Schwartz 1924), "sarcoid leiomyoma" (Krahnert 1952), "parasitic granuloma" (Cohrs 1966), "parasitic neoplasia" (Helmboldt & Wyand, 1972), "verrucous typhlitis," and "leiomyoma" (Menezes et al. 2003). Divergent opinions persist in the literature regarding whether these changes represent granulomatous or fibrohistiocytic tissue, fibrovascular proliferations, fibrous hyperplasia, or bona fide neoplasms like leiomyomas (Balaguer et al. 1992; Halajian et al. 2013; Mendonça, 1953). Indeed, submucosal and muscular layers in the cecum frequently show necrotic areas, giant cell granulomas, and nematode remnants (Halajian et al. 2013; Mendonça 1953), sometimes accompanied by clear evidence of neoplastic nodules (Balaguer et al. 1992; Mendonça 1953). Our findings revealed a predominance of proliferative spindle-cell nodules with minimal inflammatory components, and immunohistochemical analysis confirmed these proliferations as predominantly myofibroblastic or pericytic rather than leiomyomatous, thus refining the current understanding of these parasite-induced proliferative lesions.

In a previous study, Himmel and Cianciolo (2017) detected nodular mesenchymal cell proliferations in the liver and lungs of pheasants, suggesting metastasis from the intestine despite no apparent granulomatous inflammation or intralesional nematodes in those tissues. Our histopathological investigation revealed necrotic foci, inflammatory cell infiltrations, and

connective tissue proliferations within the submucosa and tunica muscularis of the cecum but no metastatic spread.

Our immunohistochemical results differ from those previously reported by Himmel and Cianciolo (2017), who demonstrated widespread positivity for vimentin and S-100 along with negativity for desmin and SMA, indicative of a neurofibromatous origin. In our case, spindle cells were weakly reactive for vimentin and α-SMA, mostly negative for S-100 (only sporadic focal reactivity), and negative for desmin. Although prior studies described leiomyomas associated with *Heterakis* sp. (Balaguer et al. 1992; Griner et al. 1977), the immunophenotype observed here—prominent α-SMA and vimentin, combined with minimal or incidental S-100 staining—more accurately aligns with a PWT or possibly a myofibroblastic proliferation rather than a fully differentiated leiomyomatous or neurofibromatous tumor (Chijiwa et al. 2004). This aligns with the concept that *Heterakis* infections can prompt a range of mesenchymal proliferations, including PWT-like nodules in pheasants. Additionally, Masson's trichrome staining demonstrated only focal collagen deposition at the periphery of these parasite-associated nodules, whereas the central spindle cell proliferations lacked dense collagen and exhibited a mildly muscle-like or myofibroblastic appearance. This limited collagen further supports the notion of a perivascular or myofibroblastic origin rather than a purely fibrous hyperplasia.

Chronic *Heterakis* infection remains the principal driver of these cecal tumors, presumably via sustained local injury, prolonged inflammation, and growth factor release (Boros et al. 2020). Eventually, fibroblasts, pericytes, or precursors of vascular smooth muscle can undergo abnormal clonal proliferation, leading to a neoplasm (Menezes et al. 2003). Although H. isolonche typically invades the cecal wall and is more traditionally considered tumorigenic, H. gallinarum—from the cecal lumen—has also been involved in cecal nodules (Menezes et al. 2003). Host-specific immune responses likely determine whether fibroplastic or pericytic proliferation ensues. Previous differentials included purely inflammatory granulomas, leiomyomas, fibrosarcomas, schwannomas, and reactive myofibroblastic nodules. Immunohistochemistry is crucial to distinguish these entities: leiomyomas show strong desmin positivity, and nerve sheath tumors express S-100 reactivity (Chijiwa et al. 2004). In our case, the prominent vimentin and α-SMA positivity, rare S-100 labeling, and desmin negativity highlight a myofibroblastic lesion with minimal neurogenic differentiation. Additionally, the organized whorling pattern around blood vessels supports a perivascular origin rather than random fibroplasia. Although rare, metastatic behavior has been documented (Himmel & Cianciolo, 2017); our case did not show metastases, but repeated exposures or co-factors could potentially incite more aggressive transformations.

From a clinical standpoint, nodular typhlitis can initially go unnoticed until worm burdens become significant. Despite the use of antibiotics and supportive care, the current outbreak has been marked by a high mortality rate—underscoring just how severe this parasitic infection is and reinforcing the urgent need for targeted anthelmintic treatment. As the disease progresses, affected birds may present with chronic diarrhea, emaciation, or even intestinal obstruction, including intussusception (Menezes et al. 2003). By the time multifocal tumors form in the

cecum, conservative treatment is generally unavailing. Prevention and early intervention are crucial in managing *Heterakis* infections in pheasants. Regular fecal screenings for *Heterakis eggs*, strict deworming protocols, and strategies to disrupt the parasite's life cycle—such as minimizing soil exposure and controlling earthworm populations—are essential in maintaining healthy flocks. In cases where advanced nodular lesions develop, severely affected birds may need to be culled to safeguard overall flock health. While these tumors are benign in that they do not typically metastasize, they can significantly impair intestinal function and, if extensive, may prove fatal (Menezes et al. 2003). Veterinarians should include *Heterakis* infection in their differential diagnoses when evaluating pheasants with chronic weight loss and severe cecal pathology.

Additionally, recognizing that many of these lesions are perivascular wall tumors broadens our understanding of how chronic parasitic infections contribute to neoplastic transformation in birds. Similar to Spirocerca lupi in canines, *Heterakis* infections in pheasants demonstrate how persistent inflammation and tissue repair can lead to tumor formation (Boros et al. 2020). Future research could focus on the molecular characteristics of these pericytic proliferations to further elucidate the mechanisms driving parasite-induced neoplasia.

## 5. CONCLUSION

Overall, our results reinforce the notion that *Heterakis* nematodes can incite significant pathological sequelae, including PWTs, thereby highlighting the need for vigilant parasite management in pheasant flocks and greater awareness of infection-induced tumors in avian pathology.

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## Conflict of Interest

The authors declare no conflict of interest.

## Author Contributions

VI: Conception, histopathological diagnosis, interpretation of immunohistochemical results, and manuscript writing and revision.

ST, AM, GO: Necropsy examination, tissue processing, histopathological staining, and manuscript writing.

MFP: Parasitological examination and species identification.

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Research Article

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# The Effects of Lacaune×Hungarian Merino Crossbreeding on Fertility, Prolificacy, and Lamb Survival Under Semi-Intensive Conditions

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## ABSTRACT

Sheep have been a fundamental part of human civilization since their domestication approximately 10,000 years ago in the Fertile Crescent. Selective breeding has significantly enhanced their productivity, leading to improved milk yield, wool quality, and meat production. Among sheep breeds, Lacaune and Merino are widely recognized for their superior milk and wool traits, respectively. This study evaluates the reproductive performance of Lacaune × Hungarian Merino crossbred ewes under semi-intensive conditions in Aksaray, Türkiye. A total of 72 Hungarian Merino ewes were mated with four Lacaune rams, and their reproductive performance was analyzed. In this study, the conception rate, birth rate, single birth rate, twin birth rate, triplet birth rate, fecundity, and litter size were recorded as 91.47%, 98.48%, 57.57%, 39.39%, 3.04%, 1.33, and 1.45, respectively. Additionally, the weaned lamb rate and lamb survival were calculated as 1.25 and 93%, respectively. The findings of this study align with previous research on Lacaune, Merino, and their crossbreeds, demonstrating that crossbreeding can enhance reproductive traits even in challenging environmental conditions. The results suggest that Lacaune×Hungarian Merino crossbreeding could be an effective approach to sustain high litter size and lamb survival rates in Türkiye. In conclusion, crossbreeding studies need to be expanded to include Türkiye's native sheep breeds with a conscious breeding approach under controlled management conditions to improve and sustain animal production.

## 1. INTRODUCTION

Sheep are considered one of the earliest domesticated animals in human history and played a crucial role in the Agricultural Revolution. It is believed that they were domesticated around 10,000 years ago in the Fertile Crescent, which includes present-day Türkiye, Iran, and Iraq. The ancestors of modern sheep were wild mouflons, which were widely found in Asia and the Middle East. (Zeder, 2008). Instead of hunting these animals, humans began to breed them in controlled environments to obtain a sustainable source of food, clothing, and other essential resources (Zeder, 2008).

The domestication process provided significant advantages to human communities. Sheep supplied valuable resources such as meat, milk, and wool, supporting the transition to a settled lifestyle (Doyle et al. 2021). In particular, wool production played a crucial role in the development of clothing and the textile industry. Over time, domesticated sheep became more docile, and selective breeding helped enhance desirable traits such as milk quality, wool yield and meat quality (Hopkins et al. 2011; Doyle et al. 2021; Turgut et al. 2023; Koca et al. 2023; Turgut et al; 2024).

Lacune sheep are widely bred in France and are known for their high milk yield. One of their most notable traits is their exceptional performance in milk production. The milk obtained from Lacune sheep is used in the production of high-quality dairy products. Additionally, their resilient structure and adaptability to harsh environmental conditions make them suitable for breeding in various climates (Barillet et al. 2001). Merino sheep, on the other hand, are renowned worldwide for producing the finest-quality wool and meat. Originating from Spain, this breed has become widely established in Australia and other countries over time (Behrem and Gül, 2022; Anaya et al. 2024). Merino wool is highly valued in the textile industry due to its fine fiber structure and superior quality. Moreover, Merino sheep are known for their high adaptability, making them well-suited for breeding in both cold and hot climates (Sawyer et al. 2021). Merino sheep are used to enhance production traits of native Turkish sheep breeds by crossbreeding and their crosses are preferred for higher production traits by farmers in Türkiye (Behrem and Gül, 2022; Atav et al. 2023).

In livestock industry, crossbreeding different breeds to enhance productivity and develop superior genetic traits is a common practice. In this context, the crossbreeding of sheep emerges as a significant option for farmers seeking high animal production. Increasing genetic diversity through crossbreeding may enhances production traits and disease resistance of sheep, making herd management more efficient. The first advantage is increased genetic diversity. Crossbred sheep inherit the strong traits of their parent breeds, making them healthier and more robust (Tesema et al. 2023). For example, crossing a high-milk-yield breed with a native breed can produce sheep that are both productive and resistant to harsh conditions (Černá et al. 2023). Secondly, meat and wool quality can be improved. Through crossbreeding, meat yield can be increased, and finer, higher-quality wool can be obtained (Tesema et al. 2023). This benefits both farmers, by boosting economic returns, and consumers, by providing better products. Finally, crossbred sheep tend to have stronger disease resistance. Crossbreeding helps prevent genetic disorders common in specific breeds

and enhances the immune system of the offspring (Habtegiorgis et al. 2025). These advantages make crossbreeding an essential tool in sustainable sheep farming, ensuring a more profitable and efficient production process.

This study will explore the effects of Lacaune X Hungarian Merino crossbreeding on reproductive traits such as fertility, prolificacy, and lamb survival under semi-extensive conditions.

## 2. MATERIAL AND METHODS

### 2.1. Animals

The study was carried out using retrospective data of a farm in Aksaray city, which has harsh climate conditions, Türkiye. In the study, a total of 72 Hungarian Merino ewes and 4 Lacune rams were used as animal material. In the study, Lacune rams were mated with Merino ewes. All animals have undergone nutritional flushing before mating. Synchronization of estrus was not performed. Flock mating was performed and rams were with ewes throughout the season. All ewes were numbered using paint stamp (Fig. 1).

Pregnancy detection was performed by an expert veterinarian. Pregnant ewes were feed by 1.5 kg alfalfa and 0.3 kg barley. Feeding was performed twice daily. In addition, ewes reached the pasture 4 hours daily. Following parturition, lambs were placed separate paddock (5 m2) with their dams. All lambs were reached colostrum in first 24 hours by suckling their dams.

During the first two weeks, ewes and their lambs were feed in the individual paddocks. Following two weeks, creep feeding was performed to the lambs. All lambs were reached the finely chopped alfalfa and concentrate creep feed (Tarım Kredi Yem, Türkiye) ad libitum gradually in addition to suckling. All ewes and lambs reached to the water ad libitum.

### 2.2. Reproductive traits

In the study, total number of ewes, the number of pregnant ewes, the number of ewes giving birth, the number of lambs born, birth types (single, twin, and triplet), and the number of weaned lambs were recorded to evaluate the effects of LacuneXMerino crossbreeding reproductive performance. When all lambs weaned, reproductive phenotypes were calculated as follow:

Conception rate: the number of pregnant ewes/ total the number of ewes

Birth rate: the number of ewes giving birth/ total the number of ewes

Stillbirth rate: the number of ewes giving birth to stillborn/ total the number of ewes

Infertility rate: the number of infertile ewes/ total the number of ewes

Single birth rate: the number of ewes giving birth single / total number of ewes giving birth

Twin birth rate: the number of ewes giving birth twin / total number of ewes giving birth

Triplet birth rate: the number of ewes giving birth triplets / total number of ewes giving birth

Fecundity: the number of lambs born/ total number of ewes

Litter size: the number of lambs born/ total number of ewes giving birth

Weaned lamb rate: the number of weaned lambs/ total the number of ewes

Livability: the number of lambs born / the number of weaned lambs

## 3. RESULTS

In the study, 66 ewes were diagnosed as pregnant while six ewes were not pregnant. A total of 65 ewes were given birth healthy while one ewe has given birth stillborn. In the study, 38 of the births were single, 26 were twins, and two were triplets. And, 96 lambs born from 66 ewes during the season. However, six lambs died before weaning. Reproductive performance of ewes was summarized in the Table 1.

**Table 1.** Reproductive performance of ewes

| Traits | n | Rate |
|---|---|---|
| **Total ewes** | 72 | |
| **Conception rate** | 66/72 | 91.67% |
| **Birth rate** | 65/66 | 98.48% |
| **Stillbirth rate** | 1/66 | 1.52% |
| **Infertility rate** | 6/72 | 8.33% |
| **Single birth rate** | 38/66 | 57.57% |
| **Twin birth rate** | 26/66 | 39.39% |
| **Triplet birth rate** | 2/66 | 3.04% |
| **Litter size** | 96/66 | 1.45 |
| **Fecundity** | 96/72 | 1.33 |
| **Weaned lamb rate** | 90/72 | 1.25 |
| **Livability** | 90/96 | 93% |

## 4. DISCUSSION

Reproductive traits in ruminants are influenced by various factors, including genetic components (Turgut and Koca, 2024; Turgut et al. 2024; Koca et al., 2024a), management practices (Koca et al., 2024b), and nutrition (Robinson et al., 2006; Bisinotto et al., 2018).

Lacaune sheep are primarily raised under intensive conditions worldwide due to their superior milk yield and quality (Jimenez et al., 2020; Zvonko et al., 2022). In addition to their high milk production, Lacaune sheep are known for their strong reproductive traits, including high conception rates and litter sizes. Under intensive management, Lacaune ewes typically have a litter size ranging from 1.4 to 1.6 (Jimenez et al., 2020). Litter size plays a crucial role in ensuring the sustainability of sheep populations and overall livestock production (Turgut and Koca, 2024). Because of their favorable reproductive and milk production traits, Lacaune sheep are frequently crossbred with other breeds to enhance milk yield in crossbred animals. A study conducted in Spain found that Lacaune × Manchega crosses exhibited similar milk production and reproductive traits as purebred Lacaune sheep (Jimenez et al., 2020). Similar results have been reported in Turcana sheep in Romania. The Turcana breed produces an average of 78 kg of milk per lactation, with a high milk fat and protein content. According to Sauer et al. (2016), Lacaune × Turcana F1 crosses yielded 109 kg of milk per lactation, and their milk quality was comparable to that of both Lacaune and Turcana sheep. These findings suggest that crossbreeding native sheep breeds with Lacaune could be an effective strategy to improve both litter size and milk production. Over the past few decades, Lacaune sheep have been imported from Europe to Türkiye due to their high milk yield and reproductive efficiency. They are now raised under both intensive and semi-intensive systems, with some breeders crossbreeding them with local sheep populations to

improve litter size and milk productivity, which is the focus of this study.


**Fig. 1.** A: Lacune ram and Hungarian Merino ewe mating, B: Hungarian Merino ewes, C: Newborn lambs, D: Cross-bred Lacaune$^{X}$Hungarian Merino ewe (F1)

On the other hand, Merino sheep are one of the most significant breeds globally, primarily known for their high-quality wool. However, they are also valued for their meat production and adaptability to various environments. Merino sheep and their crossbreeds are widely preferred in leading sheep-breeding countries, including Türkiye, due to their superior meat production and reproductive traits (Behrem and Gül, 2022; Atav et al., 2023). A study on crossbred Merino sheep (German Black Head Mutton × Karacabey Merino) found a twinning rate of 53% and a triplet birth rate of 6%. Additionally, the lamb survival rate was reported to be 92.5%, and the litter size was 1.66 under semi-intensive conditions (Ceyhan et al., 2009). However, reproductive performance is highly dependent on management practices. Another study found that under traditional extensive conditions in Türkiye, Central Anatolian Merino sheep had a litter size of 1.12 and a twinning rate of 26.7% (Aktaş et al., 2016). Similar results were reported by Aktaş et al. (2015). Furthermore, Behrem et al. (2025) reported a conception rate of 92.3%, a fecundity rate of 1.16, and a litter size of 1.26 for Central Anatolian Merino under extensive conditions.

In this study, the conception rate, single birth rate, twin birth rate, triplet birth rate, fecundity, and litter size were recorded as 91.47%, 57.57%, 39.39%, 3.04%, 1.33, and 1.45, respectively. Additionally, the weaning rate and lamb survival rate were calculated as 1.25 and 93%, respectively. These results align with previous studies on Lacaune, Merino, and their crossbreeds. It is important to emphasize that this crossbreeding study was conducted under semi-intensive conditions with a traditional sheep-breeding approach in harsh environmental conditions in Aksaray province.

## 5. CONCLUSION

In conclusion, the high conception rate, twinning rate, fecundity, litter size, and lamb survival rate observed in this crossbreeding study in semi-intensive conditions may provide valuable insights for sustaining livestock production in Türkiye's challenging climatic regions. However, these crossbreeding studies need to be expanded to include Türkiye's native sheep breeds with a conscious breeding approach under controlled conditions.

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## Conflict of Interest

There is no conflict of interest

## Ethical Statement

In this study, ethical approval was not required because retrospective data of Gökduman Sheep Farm between 2021-2022 were used and there was no animal intervention.

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Case Report

Veterinary Science Reports

# Surgical Management and Outcome of Atresia Coli in a Holstein Calf

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## ABSTRACT

Atresia coli is a congenital defect in neonatal calves characterized by the absence or obstruction of a segment of the colon, resulting in intestinal blockage. In such cases, treatment options are limited to surgical intervention or euthanasia. Treatment decisions should primarily consider the animal's general condition, postoperative care, potential complications, and associated costs. In this case report, a colonic fistula (colostomy) was created in a Holstein calf, which was hospitalized and monitored for six months. No significant complications were recorded during the observation period. The calf adapted well to the farm environment; however, its development was slower compared to its peers, and it appeared visibly weak at six months of age. This case highlights the importance of early diagnosis, appropriate surgical techniques, and meticulous postoperative care in achieving favorable outcomes.

## 1. INTRODUCTION

Atresia coli is a congenital condition characterized by the complete absence of lumen formation in any segment of the colon. The most commonly affected intestinal region is the spiral segment of the ascending colon (Steiner, 2004; Anderson, 2008; Meylan, 2008). While the condition is suspected to have a hereditary basis, environmental factors may also play a contributing role. Clinically, calves initially appear healthy; however, over time, progressive bilateral abdominal distension, abdominal pain, intermittent straining, increasing depression, and weakness become evident. The sucking reflex is typically present in the early stages but diminishes as the disease progresses, eventually leading to anorexia. The most notable symptom is the absence of defecation despite the presence of a normally developed anus and rectum (Fierheller, 2002; Steiner, 2004; Mulon, 2005; Anderson, 2008; Meylan, 2008).

In most cases, diagnosis can be established through anamnesis and physical examination findings (Steiner, 2004; Meylan, 2008). However, imaging techniques such as radiography and ultrasonography are utilized for differential diagnosis, while definitive diagnosis is achieved through diagnostic laparotomy (Fierheller, 2002; Steiner, 2004; Anderson, 2008; Meylan, 2008). The management of atresia coli cases relies on early diagnosis, supportive care, and surgical intervention, all of which are critical for a favorable prognosis (Azizi et al., 2010). In cases where surgical treatment is not accepted by the owners, immediate euthanasia is recommended, as progression of the condition often leads to fatal complications such as autointoxication, circulatory failure, or peritonitis due to intestinal perforation (Meylan, 2008).

## 2. CASE PRESENTATION

A six-day-old male Holstein calf was presented to the Surgery Clinic of Selcuk University Faculty of Veterinary Medicine with a history of an absence of defecation and abdominal distension. Clinical examination revealed a normal respiratory rate (30/min) and heart rate (120/min), but the body temperature was below normal (37.0°C). Additionally, marked abdominal distension, more pronounced on the right side, a diminished sucking reflex, and moderate dehydration were observed.

Finger exploration through the rectum did not reveal the presence of meconium. The rectal examination using a flexible catheter revealed that the catheter had advanced approximately 20 cm. Irrigation with warm physiological saline resulted in the return of a mucus-like fluid (Fig. 1). A distended cecum and colon were palpable in the right paralumbar fossa. Based on the clinical history and examination findings, atresia coli was suspected. Lateral abdominal radiographs confirmed the diagnosis by demonstrating gas-distended intestinal segments. Following owner consent, immediate surgical intervention was planned.

In the preoperative period, the primary focus was on restoring body temperature and correcting dehydration. Intravenous rehydration was initiated using 0.9% NaCl (Polifarma, Türkiye). After corrective fluid therapy, 1.5 mL of subcutaneous meloxicam (Bavet Meloxicam, Bavet, Türkiye) and 3.2 mL of intramuscular benzylpenicillin + dihydrostreptomycin (Reptopen, 50 mL, Ceva, Türkiye) were administered. The right abdominal wall was widely clipped, ensuring the paralumbar fossa remained the central focus. Sedation was induced with an intramuscular injection of 0.4 mL of xylazine (XYLAZIN BIO 2%, Bioveta, Czech Republic), followed by local infiltration anesthesia with 15 mL of lidocaine (Adokain, Sanovel, Türkiye) applied to the right paralumbar fossa.

**Fig. 1.** Appearance of mucous-like content coming from the rectum after irrigation.

The calf was positioned in lateral recumbency on the surgical table, and the surgical site was prepared aseptically and draped in a sterile manner. A routine laparotomy was performed through the right paralumbar fossa. After entering the abdominal cavity,

the organs were examined for pathological changes and/or anomalies. The atretic intestinal segment (blind end) was identified, with atresia occurring in the spiral colon (Fig. 2).

Despite intestinal distension, no perforation or intra-abdominal adhesions were detected. The segment of the descending colon connected to the rectum was found to be markedly thin, short, and lacking a normal physiological appearance. The accumulated gas in the distended cecum and spiral colon was relieved via cecal puncture. The atretic blind intestinal segment was then bluntly dissected and mobilized approximately 15 cm from the surrounding tissues.

Since anastomosis was not feasible, a colostomy was performed. The atretic intestinal segment was exteriorized and clamped using intestinal forceps, after which its blind end was resected. Extreme caution was taken to prevent contamination while the intestinal contents were evacuated, and the free intestinal segment was thoroughly flushed with physiological saline. The intestinal section was then sutured to the peritoneum and transverse abdominal muscles in a circular manner with 6-8 interrupted seromuscular sutures using polyglycolic acid no. 2-0 (Alcasorb, Katsan, Türkiye). The same procedure was repeated a little more superficially to attach it to the external abdominal oblique muscle. Finally, the intestinal end was sutured using with interrupted sutures to include the skin. The operation line outside the fistula was closed in accordance with the routine (Fig. 3).

## 3. POSTOPERATIVE CARE AND OUTCOME

Postoperatively, the calf was subjected to close monitoring in the hospitalisation unit for a period of one month, during which time it received the standard postoperative care. Wound dressings were applied for a period of 10 days, and antibiotic therapy was continued. Defecation was observed the day after surgery, thus allowing for the gradual introduction of oral feeding. During the process of wound care, the fistula site was irrigated with warm water, and the suture line was treated with terramycin antibiotic spray (Terramycin, Zoetis, Germany). Sutures were removed on day 10, and no postoperative complications were encountered during this period.

After weaning, the calf was released to other calves of the same age on the university farm. The only problem encountered in the calf, which was under the supervision of a caretaker and checked by us at regular intervals, was the adhesion that occurred in the fistula hole when it was approximately 2 months old. Since this was noticed early, it was easily opened with a simple intervention.

The surgical intervention was well-tolerated by the calf, allowing it to resume its normal activities. The fistula orifice remained inconspicuous due to hair coverage, and defecation occurred without complications. However, the most notable concern was the calf's significantly delayed growth compared to its peers. By six months of age, it had reached a live weight of only 128 kilograms (Fig. 4).

## 4. DISCUSSION

Atresia coli is the most commonly encountered intestinal anomaly in calves after anorectal malformations. Its etiology remains unclear. The fact that affected calves typically present with similar histories and clinical symptoms often facilitates accurate diagnosis. Although this anomaly has been reported in various breeds, Holstein calves appear to be the most frequently affected. In cases of atresia coli, which are fatal if left untreated, early and accurate diagnosis, effective surgical intervention, and meticulous postoperative care play a crucial role in case management (Fierheller, 2002; Steiner, 2004; Mulon, 2005; Meylan, 2008).

Early and correct diagnosis is very important as it will enable early intervention. In this context, contrast radiography (Seong et al., 2011; Abouelnasr et al., 2012; Saibaba et al., 2016), colonoscopy (Onyay et al., 2020), and some biomarkers (Yildiz et al., 2018) have been reported to have diagnostic importance. In calves that have been diagnosed early and therefore have not yet developed complications from atresia, the only treatment option is surgical intervention. In cases of atresia coli, anatomosis, cecostomy, and colostomy are applied operatively. The intestinal segment where atresia is formed and the type of atresia play a decisive role in determining which of these techniques will be applied (Koc et al., 2001; Fierheller, 2002; Steiner, 2004; Mulon, 2005; Meylan, 2008). In the presented case, the descending colon was not suitable for anastomosis and the type of atresia (Type III) made colostomy appropriate. The laparotomy was performed through the right abdominal wall and the literature data (Fierheller, 2002; Azizi et al., 2010) were taken into account in the positioning of the colon fistula.

In calves that have undergone operative treatment, different survival rates and therefore different opinions regarding prognosis have been reported. Koc et al. (2001) stated that the survival rate in calves diagnosed with atresia coli is dependent on the time elapsed after birth, the general condition of the animal, the supportive treatment given and the suitability of the intestinal segment with atresia for anastomosis. Kilic and Sarierler (2004) similarly related the survival rate to early diagnosis, the affected bowel segment and the success of operative intervention. Atalan et al. (2003), Durmus (2009), Göksel (2015), and Yurdakul (2019) reported that the survival rate was low in calves with atresia coli. Alkan et al. (2002) stated that the colostomy technique can be used for short-term survival in calves with poor condition. Similarly, Azizi et al. (2010) reported that

**Fig. 2.** Appearance of blindly terminated atretic intestine.

the survival rate was 73% after colostomy surgery on 14 calves and that it could be used for short-term survival.

**Fig. 3.** Postoperative view of the operating line and colostomy fistula.

In the presented case, the calf demonstrated an ability to adapt to its normal life and to the hierarchical order within the herd, reaching the age of six months without complications related to the surgical intervention. However, when literature data is evaluated, it is seen that the focus is on complications encountered in the postoperative period. The most prevalent complications include peritonitis, anastomosis defects, diarrhea, incisional infections, chronic cecal dilatation, spiral colon obstructions and obstructions due to intestinal adhesions (Steiner, 2004; Mulon, 2005; Anderson, 2008; Meylan, 2008). In this context, the significance of operative technique and postoperative management becomes particularly salient. In the presented case, during the colostomy procedure, the intestinal segment was sutured to different muscle groups in the form of two different circular lines. In this way, possible fistula complications are prevented and a resistance is created that prevents the continuous flow of feces depending on the tone of the muscles. Therefore, unless the intestines reached a certain level of fullness, there was no feces discharge, and contamination that would occur due to the continuous flow of feces was prevented to some extent.

Another important issue is that the postoperative process is managed directly by a member of the operation team. In the presented case, since the entire process was under our control, medical treatment was continued without interruption and no management weakness was allowed that would lead to complications. In the reported cases (Koc et al., 2001; Azizi et al., 2010), it was observed that postoperative follow-up and initiative were left to the patients' owners.

**Fig. 4.** Appearance of the calf at six months of age.

Although the process was well managed in our case, another important point that should be emphasized is that our calf could only reach 128 kg live weight at the age of 6 months. This observed developmental delay has also been reported by other researchers (Koc et al., 2001; Alkan et al., 2002; Kilic and Sarierler, 2004; Göksel, 2015).

## 5. CONCLUSION

In conclusion, when considering all aspects of cases of atresia coli encountered in calves, it is clear that the process is quite complex. In these types of anomalies, which require extensive studies from an economic perspective, it should be remembered that operative intervention is only aimed at keeping the calf alive. Naturally, euthanasia appears as another option. However, if treatment is decided upon, operative technique and postoperative care have been shown to be very important.

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Research Article

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# Macroscopic Development of the Scapula in Sheep (*Ovis aries*) During the Last Two Trimesters of Gestation

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## ABSTRACT

This study investigated the morphological and morphometric development of the fetal scapula in sheep (*Ovis aries*). Hamdani crossbred sheep fetuses, obtained from slaughtered healthy animals in Siirt province, were used for the study. Using a formulation, gestational ages were calculated from crown-anus distance (CRL) measurements. Following careful dissection, morphometric analyses of scapula samples were conducted utilizing ImageJ software. Key measured parameters included diagonal length (DL), dorsal scapular width (SW-d), medial scapular width (SW-m), ventral scapular width (SW-v), scapular spine length (SSL), scapular cartilage width (SCW), scapular cartilage length (SCL), fossa supraspinata width (FSSW), fossa infraspinata width (FISW), and fossa subscapularis width (FSW). Results demonstrated significant and progressive increases in scapular bone dimensions and specific morphological regions with advancing fetal age. These findings will contribute significantly to understanding prenatal ossification processes and skeletal growth dynamics in sheep. From a clinical perspective, these data will provide reference values for veterinary orthopedic evaluations and will support further studies in animal husbandry and anatomical research.

## 1. INTRODUCTION

Sheep (*Ovis aries*) have historically held significant economic, social, and cultural roles within agriculture and livestock activities. They are widely farmed globally, primarily for products such as meat, milk, wool, and leather, making them economically important animals (Gebremedhin et al., 2020). Recent advances in veterinary medicine and animal husbandry have significantly improved methods for monitoring and enhancing sheep health. These methods facilitate healthy growth, enable early disease detection, and thus substantially contribute to improved productivity and animal welfare (Silva et al., 2022; Abe et al., 2024).

The skeletal system is critically important for mobility and functional health in sheep, as in all vertebrate species. Bones serve as muscle attachment points, enabling movement, and providing fundamental structural support to the body (König & Liebich, 2020). Among these bones, the scapula (shoulder blade) is especially crucial due to its role in determining the range of motion and weight-bearing capacity of the forelimbs. It enhances movement efficiency and stabilizes the limbs by offering key muscle attachment sites. Therefore, understanding normal morphological and developmental features of the scapula is vital for orthopedic interventions, trauma management, and accurate assessment of anatomical variations (Akçasız et al., 2024).

Bone development during the fetal period is a complex process beginning in the embryonic stage and continuing until birth. This process encompasses ossification, cellular differentiation, and mineralization phases (Hall, 1988). Particularly in the second and third trimesters, rapid bone development and differentiation occur. Significant anatomical and histological changes are observed in critical bones like the scapula during these stages (Hall, 1988; Fisher, 1998). Understanding the details of ossification speed and shaping processes during these periods is essential for comprehending potential developmental anomalies and skeletal growth issues (Ogden & Philips, 1983). Understanding developmental processes during the fetal period can enhance early diagnosis and intervention capabilities, thereby reducing economic losses and improving herd health.

This study aims to thoroughly examine the morphological and morphometric parameters of scapular development during fetal stages in sheep. These parameters include bone size, shape, proportions of various regions, ossification levels, and morphological variations. The findings of this study are expected to clarify critical periods of fetal bone development, provide valuable insights for clinical veterinary practices, and serve as a foundation for future research. It is anticipated that the research results will be a valuable reference for sheep breeding, veterinary orthopedics, and regenerative medicine applications. Additionally, the results are expected to guide future skeletal system research, contributing significantly to productivity and animal health in sheep farming.

## 2. MATERIALS AND METHODS

In this study, fetuses obtained from clinically healthy, pregnant sheep slaughtered in specialized slaughterhouses in Siirt province were utilized.

**Fig. 1.** Lateral view of a 70-day-old sheep fetus illustrating the anatomical positioning and morphological appearance of the scapula during the fetal development period

Fetuses were carefully extracted from the collected uteri under controlled conditions, taking particular care to minimize contamination from amniotic fluids and other potential contaminants. Following extraction, fetuses were immediately transferred under sterile and appropriate conditions to the laboratory for further processing and detailed examination. It is important to note that twin pregnancies were not included in this study.

Upon arrival at the laboratory, fetuses underwent careful cleaning to remove residual amniotic fluids and other potential contaminants. They were then promptly fixed and meticulously preserved to maintain structural integrity and minimize any post-mortem morphological changes that could affect morphometric accuracy. Gestational age determination was achieved through precise crown-rump length (CRL) measurements, calculated using the established formula $X = (Y + 17) \times 2.1$, where X represents gestational age in days and Y represents the CRL length in centimeters (Noakes, Parkinson & Gary, 2001; Işbilir & Güzel, 2024; Güzel & Işbilir, 2024).

Subsequently, fetuses were categorized into the following groups based on their gestational ages: 50–60 days (n=2), 60–70 days (n=6), 70–80 days (n=2), 80–90 days (n=1), 90–100 days (n=1), 100–110 days (n=2), 110–120 days (n=2), and 120–130 days (n=2). Scapula samples were precisely dissected and carefully separated from surrounding soft tissues under magnification to ensure accurate and consistent anatomical evaluation. (Fig. 1, Fig. 2).

Measurement points were determined by taking the study of Sasan et al. (2018) as a guide. Measurement parameters are shown in Figure 2. The measurements are as follows:

1. DL: Diagonal Length: Coracoid process to caudal angle length
2. SW-d: Dorsal Scapular Width
3. SW-m: Medial Scapular Width
4. SW-v: Ventral Scapular Width
5. SSL: Scapular Spine Length
6. SCW: Scapular Cartilage Width
7. SCL: Scapular Cartilage Length
8. FSSW: Fossa Supraspinata Width
9. FISW: Fossa Infraspinata Width
10. FSW: Fossa Subscapularis Width

Detailed morphometric analysis was performed utilizing ImageJ software (National Institutes of Health, Bethesda, MD, USA), providing reliable and precise measurements. Data from detailed morphometric assessments were evaluated to identify clear developmental trends and

correlations between specific anatomical measurements and fetal gestational stages.

## 3. RESULTS

The findings revealed a marked, progressive, significant increase in scapular dimensions associated with advancing fetal age.

**Table 1.** Descriptive statistical values for morphometric measurements of the fetal scapula in sheep (cm).

| | Trimester | n | Mean | SE | SD | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| DL | 2 | 12 | 1.51 | 0.18 | 0.65 | 0.42 | 2.55 |
| | 3 | 5 | 4.57 | 0.29 | 0.66 | 3.7 | 5.36 |
| SW-d | 2 | 12 | 1.01 | 0.14 | 0.48 | 0.18 | 1.90 |
| | 3 | 5 | 2.90 | 0.16 | 0.37 | 2.44 | 3.36 |
| SW-m | 2 | 12 | 0.66 | 0.10 | 0.34 | 0.10 | 1.31 |
| | 3 | 5 | 1.83 | 0.09 | 0.21 | 1.60 | 2.10 |
| SW-v | 2 | 12 | 0.31 | 0.05 | 0.18 | 0.05 | 0.65 |
| | 3 | 5 | 0.87 | 0.08 | 0.17 | 0.71 | 1.12 |
| SSL | 2 | 12 | 1.26 | 0.19 | 0.64 | 0.28 | 2.34 |
| | 3 | 5 | 3.51 | 0.18 | 0.40 | 3.01 | 3.88 |
| SCW | 2 | 12 | 1.20 | 0.19 | 0.66 | 0.24 | 2.52 |
| | 3 | 5 | 4.40 | 0.07 | 0.17 | 4.22 | 4.67 |
| SCL | 2 | 12 | 0.50 | 0.07 | 0.23 | 0.14 | 0.89 |
| | 3 | 5 | 1.71 | 0.18 | 0.39 | 1.10 | 2.07 |
| FSSW | 2 | 12 | 0.23 | 0.03 | 0.11 | 0.05 | 0.47 |
| | 3 | 5 | 0.72 | 0.07 | 0.15 | 0.58 | 0.97 |
| FISW | 2 | 12 | 0.62 | 0.09 | 0.32 | 0.09 | 1.19 |
| | 3 | 5 | 1.79 | 0.10 | 0.22 | 1.46 | 1.98 |
| FSW | 2 | 12 | 0.41 | 0.66 | 0.23 | 0.05 | 0.87 |
| | 3 | 5 | 1.64 | 0.15 | 0.34 | 1.37 | 2.19 |

DL: Diagonal length (cm), SW-d: Dorsal scapular width (cm), SW-m: Medial scapular width (cm), SW-v: Ventral scapular width (cm), SSL: Spina scapula length (cm), SCW: Scapular cartilage width (cm), SCL: Scapular cartilage length (cm), FSSW: Fossa supraspinata width (cm), FISW: Fossa infraspinata width (cm), FSW: Fossa subscapularis width (cm)

Descriptive statistical data showing morphometric measurements of fetal sheep scapula at different gestational periods were presented in Table 1.

According to the study results, the diagonal length (DL) increased significantly from an average of 1.51 cm in the second trimester (range: 0.42-2.55 cm) to an averag e of 4.57 cm in the third trimester (range: 3.70-5.36 cm). As expected, in addition to morphometric parameters, cartilage scapula width and length parameters were also found to be higher in the last period of pregnancy compared to the second period.


**Fig. 2.** Morphometric measurements performed on the fetal sheep scapula. Measurements were conducted using anatomical landmarks to ensure accuracy and reproducibility. A: Lateral view of the scapula in a 92-day-old fetus, B: Costal (medial) view of the scapula in a 107-day-old fetus, C: Lateral view of the scapula in a 62-day-old fetus, D: Lateral view of the scapula in a 68-day-old fetus

## 4. DISCUSSION

The morphometric data from this study demonstrated a progressive and significant growth of the fetal sheep scapula with advancing gestational age. All measured parameters – including overall scapular length, spine length, and the widths of the supra- and infraspinous fossae – increased markedly from the second to the third trimester. These findings indicate that the second half of gestation is a critical period of rapid scapular development, consistent with general principles of fetal osteogenesis in sheep. Previous studies have demonstrated that major ossification processes and growth spurts of appendicular bones in sheep occur particularly during the second and third trimesters of pregnancy. According to Flinn et al. (2022), who studied fetal ossification patterns in domestic sheep (Ovis aries), ossification in the hind limb bones begins approximately on day 45 of gestation, with significant growth occurring in subsequent stages. Furthermore, radiographic studies report marked changes in skeletal mineralization, particularly during the second and third trimesters of gestation, indicating rapid mineralization of bony structures during this period (Güzel & Işbilir, 2024). This aligns with our observations of accelerated scapular development in the late fetal stages. This substantial prenatal growth of the scapula is biologically necessary, as the shoulder girdle must be sufficiently developed by birth to support the neonate's mobility. Sheep are a precocial species, and lambs are typically able to stand and ambulate within hours of birth; accordingly, their musculoskeletal system (including the scapula) must reach a high degree of maturity before parturition (Ahmed, 2008). The pronounced increases in scapular dimensions we observed can therefore be interpreted as the fetus's preparation for postnatal life, ensuring that the shoulder blade will have the size and strength to contribute to weight-bearing and locomotion immediately after birth.

The timing of scapular ossification observed in prior studies provides a useful framework for interpreting our morphometric results. It is well documented that the sheep scapula begins ossifying relatively early in gestation: a primary ossification center in the scapular body appears at around day 45 of gestation (Succu et al., 2023). In line with our findings, previous radiographic studies by Wenham (1981) have also documented early skeletal development in fetal sheep, noting particularly significant mineralization events during gestation. Wenham observed notable changes in skeletal mineralization occurring between 34 and 41 days of gestation, during which critical components of the axial and appendicular skeleton—including the scapula—became radiographically evident. This aligns closely with our findings of accelerated scapular morphometric growth during mid-to-late gestation, supporting the assertion that ossification processes and bone development in sheep occur extensively and rapidly during the second and third trimesters (Wenham, 1981). Similar observations regarding scapular morphometric development have been reported in other sheep breeds. For instance, Isaenkov et al. (2019) conducted morphometric analyses on Romanov sheep scapulae throughout ontogenesis, demonstrating substantial increases in scapular mass, length, and width during prenatal development and significant morphological differences between sexes. The study particularly emphasized that scapular length and width exhibit

synchronized growth patterns corresponding to increased scapular mass, supporting the notion that critical structural maturation of scapular bones occurs progressively throughout fetal life and continues postnatally (Isaenkov et al., 2019). Furthermore, Harris (1937) conducted a comprehensive radiographic and histological investigation of fetal skeletal development in sheep, highlighting critical periods of ossification. Harris documented the precise sequence of ossification centers' appearance, noting significant morphological and developmental similarities as well as differences between sheep and other mammalian species, including humans. The scapula, among other bones, was observed to develop rapidly, with an identifiable ossification center appearing early in gestation (around 45 days), emphasizing its accelerated maturation relative to humans. This aligns closely with our findings, further validating the timing and morphological changes observed in scapular development during fetal growth in sheep (Harris, 1937). Beyond sheep, similar developmental patterns are reported in other domestic ruminants, underscoring the generality of our observations. In goat fetuses (which have a gestation length comparable to sheep), primary ossification centers in the scapula also become evident around 7–8 weeks into gestation, and all scapular measurements then increase linearly with fetal age up to term (Parmar et al., 2024).

## 5. CONCLUSION

In conclusion, this study provides a comprehensive characterization of the morphometric and morphological development of the fetal sheep scapula during mid to late gestation. We found that scapular dimensions increase in a consistent, predictable manner with advancing fetal age, with significant growth spurts occurring in key parameters such as overall length, spine length, and the widths of important fossae. These results delineate the timeline by which a relatively small, predominantly cartilaginous early fetal scapula transforms into a larger, mostly ossified structure by the third trimester, ready to meet the functional demands of neonatal life. The main findings highlight that the sheep scapula undergoes rapid and coordinated growth, ensuring that by the time of birth the bone has achieved the form necessary for effective muscle attachment and limb support. Such knowledge is highly relevant both clinically and academically. Clinically, our data will serve as reference values for normal fetal development, aiding veterinarians in estimating fetal age and in the early detection of developmental abnormalities or growth retardation. Academically, the findings will enrich the understanding of veterinary developmental anatomy and will provide a basis for further research into skeletal growth and its regulation. Ultimately, by elucidating how the fetal scapula grows and matures, this work will add an important piece to the larger puzzle of prenatal musculoskeletal development and will lay the groundwork for future studies and applications in veterinary medicine and animal science.

### Ethical Statement

With the ethics committee report numbered 2025/02/06, the Siirt University Experimental Animals Application and Research Center approved the procedures used in this investigation.

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Review

Veterinary Science Reports

# Animal Welfare in Sheep: A Review of Evaluation Methods and Applications

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***Key words:*** sheep, animal welfare, ANI-35L, welfare quality

## ABSTRACT

Animal welfare has emerged as a fundamental component of sustainable livestock production, reflecting both ethical considerations and productivity outcomes. This review focuses on the assessment and practical implementation of welfare indicators in sheep. It covers behavioral, physiological, and health-related measures, including body condition scoring, fleece cleanliness, lameness, respiratory conditions, and skin lesions. Furthermore, environmental and management-related factors such as housing conditions, feeding systems, and human-animal interactions are discussed in the context of their impact on welfare. Emphasis is placed on the integration of animal-based and resource-based indicators to ensure a comprehensive evaluation framework. The paper also highlights the importance of standardized protocols and training in conducting reliable welfare assessments, while acknowledging the challenges in large-scale field applications. In conclusion, understanding and improving sheep welfare requires a multidimensional approach that bridges scientific knowledge, practical tools, and ethical responsibility.

# 1. INTRODUCTION

Animal welfare is a definition that reflects the animal's quality of life and includes the animal's mental and physical health, happiness, and well-being (Lawrence et al., 2019). The first legal movement regarding the protection of animals and the right to life was realized by the Animal Protection Law in England in 1822. The first legal basis for welfare is the Treaty of Rome issued by the European Union (EU) in 1957. The Amsterdam Treaty of May 1999 is crucial in recognizing animals as sentient beings for the first time and includes a protocol containing legal provisions on their welfare (Martinez and von Nolting, 2023). The issue of animal welfare has become a subject of debate in many parts of the world since the 1960s. With the contribution of these discussions, the Universal Declaration of Animal Rights, the most comprehensive international text on animal rights and welfare, was declared in 1978 (Antalyalı, 2009; Fidan, 2012). Today, the European Union institutions and member states have taken valuable steps in animal welfare and have introduced many legal regulations.

# 2. ANIMAL WELFARE AND ITS RELATIONSHIP WITH WELL-BEING AND ANIMAL HEALTH

Animal welfare is interconnected with the concepts of 'well-being and animal health,' and evaluating these two conditions also means evaluating animal welfare (Dawkins, 2012). In an animal husbandry enterprise, it should be determined whether animal comfort is evaluated correctly based on scientific principles. If the animal is exposed to a negative situation and is mentally affected by it, it indicates that animal welfare is applied at a low level (Yener et al., 2013).

Many different European regulations on animal welfare have been published. Although no specific rules have been applied to ovine animals, Commission Decision 2006/778/EC (European Commission 2006) states that examining animals kept for farming purposes should cover general animal welfare requirements and requirements in specific laws (Cassidy, 2009). The role of the scientific community in developing effective welfare assessment programs should be enhanced through the involvement of relevant stakeholders: producer associations, animal breeding organizations, retailer and consumer organizations, policymakers, and veterinarians. In particular, veterinarians need to assess remedial options for sick animals or animals at risk of becoming sick in small ruminant emergencies, which will improve their welfare status (Caroprese et al., 2016).

## *2.1. The Five Fundamental Rights of Animals as Set Out by the European Union Council for the Welfare of Farm Animals*

1. Animals should not be starved or dehydrated; constant access to fresh water and food to keep them healthy and fit.

2. Animals should be made comfortable; they should not be disturbed by providing appropriate environmental conditions, including shelter and resting places.

3. Animals should be kept away from pain, injury, and diseases; preventive measures should be taken against diseases, and they should be diagnosed and treated quickly.

4. Animals should be able to show their natural behaviour; space and comfortable housing for animals of the same species should be provided, and animals should be able to show their natural behaviour.

5. Animals should be kept free from fear and stress; conditions and treatment to prevent pain and suffering (Askaroglu, 2006; Scott et al., 2006).

## 3. ANIMAL WELFARE IN SHEEP

Sheep welfare is the development of animals living in harmony with each other, taking into account their physiological needs and behaviors and the fulfillment of their care and feeding under appropriate conditions. Welfare is an indicator of the animal's mental and physical quality of life (Sejian et al., 2021).

Research has shown that environmental factors (care-feeding, management, etc.) are more effective than genetic factors in determining an animal's efficiency level (Ramadan, 2012). To maintain their health and vital activities, sheep should be fed with appropriate and sufficient amounts of feed according to age, weight, behavior, physiological needs, and targeted yield. Animals should be provided with the opportunity to access sufficient feed and water in terms of quality and quantity at appropriate intervals to meet their needs. Feeding and watering equipment should be designed and positioned so that feed and water are not contaminated and animals do not harm each other. By keeping the floor dry, animals should be able to lie down, rest, stand up, and meet their other needs (Caroprese, 2008). The temperature and humidity of the shelter should be within acceptable limits. In cases where natural lighting is insufficient in animals housed indoors, eight hours of artificial lighting per day should compensate for this deficiency (Prescott et al., 2003). Cleaning the inside of shelters frequently is obligatory to prevent negative effects caused by bad appearance and odour. The tools and equipment used in shelters should be cleaned and disinfected at certain intervals and frequencies to prevent the reproduction and transmission of disease-causing agents (Yoksa, 2024).

## 4. MEASURING ANIMAL WELFARE IN SHEEP

Providing the natural living conditions of animals in the most appropriate way in breeding conditions does not mean that welfare is implemented very well. If their environment does not meet the wishes of the animals, they will react to this situation. How they react, and the severity of the reaction varies according to the animal species. In this respect, animal welfare is difficult to measure. It is easier to be determined by specialized people according to the animal species (Browning, 2022). Measuring animal welfare involves evaluating various factors, including physiological indicators, blood tests, yield parameters, and subjective assessments (Serra et al., 2018).

### *4.1. Physiological Indicators*

Life in itself is an indicator of welfare. The most basic welfare criterion is the continuation of life (Mellor and Stafford, 2004). Other criteria should be evaluated after that. Therefore, mortality rates should be examined first before determining farm animals' welfare. Some diseases can develop very rapidly and cause death. At the same time, sudden deaths due to stress can also be seen. Another physiological observation is the reproductive performance of animals. Even if the five most basic welfare criteria are

**Table 1.** Welfare Quality Principles and Associated Assessment Measures

| Welfare principle | Welfare criteria | Example of assessment measure |
|---|---|---|
| **Good feeding** | Absence of prolonged hunger | Body condition score (BCS) |
| | | Provision of supplementary feed |
| | Absence of prolonged thirst | Quality and reliability of water provision |
| **Good housing** | Comfort around resting | Cleanliness, dry lying area at all times |
| | Thermal comfort | Protection from extreme weather |
| | | Panting |
| | Ease of movement | Adequate space (housed sheep), rough terrain |
| **Good health** | Absence of injuries | Injuries |
| | | Lameness |
| | Absence of disease | Mastitis, sheep scab, footrot, lamb losses |
| | Absence of pain induced by management procedures | Castration, tail docking |
| **Appropriate behavior** | Expression of social behaviours | Social behaviours are uncommon in sheep except at breeding/lambing time. |
| | | Normal maternal behaviour |
| | Expression of other behaviours | Grazing behaviour. |
| | | Predator avoidance |
| | Good human–animal relationships | Avoidance distance. |
| | | Behaviour when handled. |
| | | Knowledge of stockpersons |
| | Absence of general fear | Reaction facing a novel situation |

met, animals not feeling comfortable in their environment may have reproductive problems. Diseases can be detected by observing or examining the animals. Especially lameness or foot-leg problems, which are frequently seen in cattle and sheep, can be determined this way (Dwyer and Bornett, 2004).

### *4.2. Blood Tests*

Stress causes many problems in animals. When stress is experienced, the body responds behaviorally and physiologically to this factor. If these two responses consume too much of the body's biological resources, the pre-pathological stage is first seen in the body, and several pathological problems occur. This situation will cause damage to animal welfare (Broom and Kirkden, 2004).). However, if the cause of stress is known or suspected, blood is taken from the animals. Stress hormone levels in the blood such as adrenal cortical activity (plasma cortisol levels), anterior pituitary activity (prolactin and β-endorphin), changes in fluid balance (hematocrit), and muscle degeneration indicators (creatine kinase levels) are analyzed to assess animal welfare. This approach enables effective traceability of welfare status (Rushen et al., 2008; Sommavilla et al., 2017).

**Table 2.** ANI 35L Welfare Assessment Framework

| Category (Total Range) | Subcategories (Score Ranges) |
|---|---|
| I. Locomotion/Social (−0.5/20.5) | • Indoor space (0.0-3.5) • Herd structure (0.0-2.0) • Replacements (−0.5-3.0) • Manger space (0.0-3.0) • Water (0.0-2.5) • Outdoor space (0.0-3.0) • Pasture months (0.0-3.5) |
| II. Flooring (−1.0/12.0) | • Comfort (−0.5-2.5) • Cleanliness (0.0-2.5) • Slipperiness-sleep (0.0-2.5) • Passage ease (0.0-1.0) • Slipperiness-transition (0.0-2.0) • Outdoor floor (−0.5-1.5) |
| III. Environment (0.0/10.0) | • Thermo-pasture (0.0-1.5) • Thermo-barn (0.0-1.5) • Outdoor paddock (0.0-1.5) • Grass quality (0.0-1.5) • Steepness (0.0-1.5) • Pasture months (0.0-2.5) |
| IV. Management (−1.0/7.0) | • Feed area clean (0.0-1.5) • Water area clean (0.0-1.0) • Rest area clean (0.0-1.5) • Equipment (0.0-1.0) • Animal checks (0.0-1.0) • Hospital pen (−1.0-1.0) |
| V. Animal (−8.0/22.0) | • Coat condition (−1.0-3.0) • Cleanliness (−1.0-3.0) • Hooves (−1.0-3.0) • Lameness (−1.0-3.0) • Lesions (−1.0-3.0) • Body condition (−1.0-3.0) • Mutilations (−1.0-1.0) • Culling age (−1.0-1.0) |

### 4.3. Animal Welfare Through Yield Parameters

The easiest method to determine welfare is to follow animal productivity. Animals react to negative situations by decreasing their productivity. Instability, such as decreased or increased feed consumption, causes yield losses. Enterprises that do not care about animal welfare will realize how important animal welfare is when they experience yield decreases (Frondelius et al., 2020).

### 4.4. Subjective Assessments

Determination based on the principle of determining the physical condition of animals by scoring method. By repeating the scoring method, one can determine how current conditions are affected and how changes over time occur. Feather scoring and determining foot and leg wounds are the most determined evaluation methods. In addition, several scoring methods can be used to evaluate the physical conditions of animal shelters (Lamon et al., 2021).

In this context, the Welfare Quality assessment system provides a structured framework for evaluating animal welfare on farms through a bottom-up scoring method. It combines various animal-based indicators into welfare criteria, which are then grouped into four main principles: good feeding, good housing, good health, and appropriate behavior. Feather condition, lameness, and cleanliness scoring are common physical measures used in the Welfare Quality protocol, especially in poultry and ruminants (Blokhuis et al., 2013).

Similarly, the Animal Needs Index (ANI) is another welfare assessment tool that integrates multiple criteria such as space allowance, flooring quality, climate, health management, and animal-human interaction. ANI allows for a semi-quantitative evaluation of housing systems based on how well they meet the behavioral and physiological needs of animals (Seo et al., 2007).

Both systems emphasize the importance of repeated scoring over time to monitor changes and ensure that any interventions positively influence animal welfare.

## 5. WELFARE QUALITY IN SHEEP

Animal welfare is an increasingly important issue for European consumers and citizens. It is an integral part of the Community's 'farm to fork' policies and one of the strategic priorities. Animal welfare is a well-established scientific discipline, and because it is multidimensional and, therefore, cannot be measured directly, several parameters have been identified and utilized instead (Brito et al., 2020). Researchers agree

that various measures should be applied to assess animal welfare. Since 2001, different welfare monitoring systems have been developed in some European countries. Most of these systems are primarily based on environmental observations, measurements assumed to influence animal welfare (Molitorisová, and Burke, 2023). However, the links between specific measurements and the welfare status of animals are not always clearly understood. Therefore, the European Commission developed the Welfare Quality Project to develop animal-based measures to assess animal welfare at the farm level, based on measuring the actual welfare status of animals in terms of their behavior, health, and physiology (Blokhuis, 2008).

This project aims to meet societal concerns and market demands, develop reliable on-farm monitoring systems, product information systems, and practical species-specific strategies to improve animal welfare. Four animal principles and twelve criteria were identified (Canali and Keeling, 2009).

## 5.1. Data Collection, Evaluation, and Welfare Scoring

After all measurements have been performed, a bottom-up approach is used to evaluate animal welfare: first, the collected data (the values obtained for the various measures on the farm) are combined to calculate the criterion scores; these criterion scores are then aggregated to calculate the principal scores, and finally, the farm is assigned to a welfare category based on its principal scores (Keeling et al., 2013).

**Table 3.** ANI 35L Welfare Categories

| Total ANI Score | Welfare Category |
|---|---|
| < 11 | Not suitable with respect to welfare |
| 11 – 16 | Scarcely suitable with respect to welfare |
| 16.5 – 21 | Little (mediocre) suitable with respect to welfare |
| 21.5 – 24 | Fairly suitable with respect to welfare |
| 24.5 – 28 | Suitable with respect to welfare |
| > 28 | Very suitable with respect to welfare |

## 5.2. Criterion Scores Calculation

While not always the case, some criteria may depend on various measures (e.g., a low body condition score could result from either hunger or illness, or both). Except for a few rare cases where the interpretations can be clearly differentiated, to avoid double-counting, the measures are assigned to a single criterion. The data produced by measures related to a particular criterion is interpreted and synthesized to produce a score that reflects the unit's compliance with the criterion. This compliance is expressed on a scale from 0 to 100 (Botreau et al., 2009).

## 5.3. Welfare Category Assignment

Four welfare categories have been established to meet stakeholders' requirements:

•Excellent: Animal welfare is at the highest level.

•Enhanced: Animal welfare is good.

•Acceptable: Welfare is above or meets minimum requirements.

•Not Classified: Animal welfare is poor and falls below an acceptable threshold.

The threshold for excellence is set at 80, for enhanced welfare at 55, and for acceptable welfare at 20. The categories do not rely on average scores; to be classified as "Excellent," a farm must score above 80 in all principles, or over 55 in two principles. Farms that score above 20 in all principles and above 55 in at least two are classified as "Enhanced." "Acceptable" farms must score above 10 in all principles and above 20 in three principles. Farms failing to meet these minimum standards are classified as "Not Classified" (Botreau et al., 2007).

## 6. ANIMAL NEEDS INDEX (ANI-35L MODEL) IN SHEEP

The animal needs index (ANI) is one of the most utilized methods for measuring animal welfare (Ofner et al., 2003). It analyses the extent to which the requirements needed for good animal welfare on farms are met under current conditions of care, feeding, and housing. This index was first applied in Austria and Germany. The animal needs index has five components to assess animal welfare (Bartussek, 2001).

The first four categories focus on locomotion/social interaction, flooring, environment, and management system, while the fifth category involves direct evaluations of the animals themselves. It has been reported that the indicators used in this system for on-farm animal welfare assessments are valid (meaning they are relevant to animal welfare), reliable (consistent in repeated measurements), and feasible (considering time and financial constraints) (Sakar et al., 2022). When this method is applied to sheep farms, factors such as the shelter's features, space per animal, litter cleaning, and ventilation systems play a significant role in the evaluation. In the ANI welfare assessment method were scored a total of 33 criteria in 5 different categories: I) Locomotion/social interaction, II) Flooring, III) Environment, IV) Management, and V) Animal-based parameters. The final score according to the ANI method varies between −10.5 and 71.5 (Napolitano et al., 2009). After the ANI assessment process is completed, businesses are classified into six different welfare parameters based on their total ANI scores. The welfare categories according to the total scores are provided in Table 3 (Bartussek, 1999).

## 7. CONCLUSION

In order to feed the rapidly increasing human population, it is necessary to fulfill the production increase targets with sustainable breeding. A significant portion of meat, milk, fleece, etc., which are the basic needs of humans, are provided by sheep. Breeding of sheep is important because sheep are more numerous and easier to care for and feed than cattle. Compliance with welfare rules is a must for healthy and highly productive sheep breeding. If welfare is not provided on the farms, health problems such as lameness, mastitis, infectious diseases, and behavioral disorders may occur. This leads to a severe decrease in fertility, meat yield, milk yield, and fleece yield in sheep. Welfare in sheep breeding means that the sheep are healthy and happy, and the products obtained from such animals are of high quality in terms of both quantity and quality. Therefore, this situation contributes to the health of people fed with healthy and quality food.

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