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Survival analysis and risk factors associated with mortality in breeding goats: A case study from Maidabino Farms, Katsina, Nigeria

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Abstract
Goat mortality is one of the most pressing constraints on small-ruminant production in Nigeria, with significant implications for food security, household income, and rural livelihoods. In northern Nigeria, where smallholder agropastoral systems predominate, goat breeding serves as a critical economic and nutritional resource; however, farm-level documentation of mortality patterns and their determinants remains sparse. This study assessed survival patterns and identified key risk factors for mortality among breeding goats at Darul Halal Farms in Katsina, Nigeria. A retrospective observational design was employed, utilising farm health records spanning September to November 2024. Data on disease occurrence, daily morbidity, and mortality counts, as well as sex, species, and breed, were systematically extracted and analysed. Diagnoses were established through clinical examination, post-mortem findings, and confirmatory laboratory testing, while the morbidity percentage was calculated as the number of affected animals divided by the total flock size. A total of 27 mortalities were recorded across 13 discrete disease events over the nine-week observation period, with daily deaths ranging from 1 to 4 animals and morbidity percentages spanning 3.70% to 14.81%. The most frequently encountered conditions were conjunctivitis and enteritis, each recorded on seven occasions, followed by foot rot (five events), contagious ecthyma or Orf (four events), traumatic injuries (three events), pneumonia (two events), and single occurrences of mastitis and miscarriage. The peak morbidity event of 14.81% occurred on 06/10/2024 during a foot rot outbreak, with additional peaks of 11.11% in October and November associated with multi-system mixed infections. Mortality in the flock resulted from a multifactorial interplay of infectious, environmental, and management-related challenges, with seasonal clustering of high-morbidity events in October suggesting a temporal pattern requiring pre-emptive intervention. Improved housing sanitation, structured vaccination programmes, strategic anthelmintic treatment, and enhanced nutritional management are strongly recommended to reduce preventable mortality and improve productivity in comparable breeding goat operations across northern Nigeria.

Keywords: Goat mortality, survival analysis, breeding goats, risk factors, small ruminants, Katsina, Nigeria

Introduction
Nigeria's current economic trajectory requires renewed focus on agricultural self-sufficiency, with small ruminant production playing a particularly vital role. Sheep and goats constitute a significant share of the ruminant trade in the country, with estimated national populations of 22.1 million and 34.5 million, respectively (Adebowale, 2012) [4]. These animals are critical resources for rural households, providing food, supporting livelihoods, and fulfilling socio-economic and cultural obligations (Adebayo *et al*., 2020) [2]. Small ruminant production contributes approximately one-third of Nigeria's agricultural gross domestic product (Adebowale, 2012) [4]. Beyond their macroeconomic significance, goats and sheep are indispensable sources of protein — both meat and milk — in developing and developed economies alike (Wesongah *et al*., 2013) [21]. In Nigeria, they provide meat, milk, household income, manure, and skin, and serve important sociocultural purposes (Okaiyeto *et al*., 2018; Okorafor *et al*., 2015) [13, 14].

Despite their importance, small ruminants — particularly goats — experience substantial morbidity and mortality due to a complex interplay of risk factors. Environmental risk factors, such as extreme temperatures, poor ventilation, and inadequate shelter, predispose animals to stress and disease. Inadequate veterinary services, including limited access to diagnosis, treatment, vaccination, and disease surveillance, further increase mortality risk (Maesela *et al*., 2017) [10]. Gastrointestinal parasitism remains a leading cause of death, with helminthoses and coccidiosis causing widespread subclinical and clinical effects on production parameters globally (Perry & Randolph, 1999; Singla, 1995) [16, 19].

Helminthosis is particularly devastating in Nigerian small ruminant herds, with approximately 20% of sheep and goats in the country dying or being slaughtered prematurely due to this condition (Kuil, 2019) [9]. The disease is closely linked to overgrazing, which forces animals to graze near faecal material teeming with infective helminth larvae (Agbajelola & Falohun, 2015) [5]. Concurrent infectious diseases — including pneumonia, tuberculosis, brucellosis, contagious ecthyma, and enteritis — also contribute substantially to mortality, especially when management is suboptimal (Singh *et al*., 2016; Gofwan *et al*., 2021) [6, 18].

Despite the well-documented importance of goat production to the Nigerian economy, there remains a paucity of farm-specific, longitudinal data on survival patterns and risk factor profiles for goat mortality in the country's northern states. Understanding these patterns at the farm level is essential for designing effective, context-appropriate interventions. This study therefore aimed to conduct a survival analysis and assess risk factors associated with mortality among breeding goats at Darul Halal Farms, Katsina, Nigeria, using retrospective farm health records for September to November 2024.

Materials and Methods

1. Study Area

The research was conducted at Darul Halal Farms, located at Ring Road, Arewa 2, 820101, Katsina, Katsina State, Nigeria (Latitude: 13.0167080°N; Longitude: 7.57210°E). Katsina Local Government Area (LGA) was created in 1976 within the then Kaduna State and is situated in the extreme northern part of Nigeria. The LGA shares borders with Jibia, Kaita, Batagarawa, and Batsari Local Government Areas of Katsina State.

The area is largely mono-lingual and mono-ethnic, with the majority of the population being Hausa/Fulani. Farming constitutes the primary economic activity in Katsina LGA, encompassing crop cultivation, poultry rearing, and the husbandry of domestic animals such as rams, cattle, and camels. Trade thrives across several local markets where agricultural commodities are actively bought and sold.

2. Study Design and Data Collection

This study employed a retrospective observational design. Data were extracted from the farm's health record book covering the period from September 2024 to November 2024. Records included comprehensive animal information encompassing sex, species, and breed. Disease diagnoses were established through a combination of clinical examination, post-mortem findings, and laboratory investigations.

The total number of mortalities, daily mortality counts, affected conditions, and corresponding morbidity percentages were tabulated and analysed. Morbidity percentage for each date was calculated as the number of sick animals divided by the total flock size at risk, expressed as a percentage.

3. Data Analysis

Data from retrospective farm records were organised into a structured database. Descriptive statistics were used to characterise disease frequency, morbidity rates, and mortality distribution over the study period. Morbidity percentages were calculated as (number of affected animals / total flock) × 100. Disease burden was assessed over time, and the co-occurrence of multiple conditions was noted to identify multi-morbidity patterns. The cumulative mortality percentage was calculated as (total mortalities / total flock) × 100.

Results

1. Overview of Mortality

A total of 27 mortalities were recorded among the breeding goat flock between September and November 2024. Daily mortality ranged from 1 to 4 animals per recorded event, with morbidity percentages ranging from 3.70% to 14.81%. Thirteen distinct disease-occurrence events were identified across the observation period. The full temporal distribution of diseases and corresponding morbidity is presented in Table 1.

2. Temporal Distribution of Diseases and Mortality

Table 1 presents the temporal distribution of diseases, mortality counts, and morbidity percentages recorded during the study period.

Table 1: Temporal distribution of diseases and corresponding mortality in breeding goats at Darul Halal Farms, Katsina (September–November 2024)

S/N	Date	Disease(s) Recorded	Mortality (n)	Morbidity (%)	Remarks
1	06/09/2024	Foot rot, conjunctivitis, ecthyma, traumatic injury	1	3.70	Mixed presentation
2	07/09/2024	Conjunctivitis, contagious ecthyma (Orf), respiratory tract infection	1	3.70	Respiratory involvement
3	08/09/2024	Conjunctivitis, Orf, enteritis	2	7.41	GI + ocular combined
4	09/09/2024	Conjunctivitis, pneumonia, enteritis	1	3.70	Multi-systemic disease
5	11/09/2024	Conjunctivitis, enteritis, foot rot, Orf	1	3.70	Polypathology
6	12/09/2024	Enteritis	2	7.41	GI infection dominant
7	13/09/2024	Foot rot, enteritis	2	7.41	Limb + GI involvement
8	15/09/2024	Miscarriage	2	7.41	Reproductive loss
9	05/10/2024	Traumatic injury, enteritis	3	11.11	Management-related
10	06/10/2024	Foot rot	4	14.81	The highest morbidity event
11	12/10/2024	Mastitis, foot rot, pneumonia	3	11.11	Complex multi-system
12	01/11/2024	Conjunctivitis, contagious ecthyma	3	11.11	Ocular + skin disease
13	12/11/2024	Traumatic injury, foot rot, conjunctivitis, diarrhoea	2	7.41	Multi-morbid event
	Total	13 disease events across 9 weeks	27	100%	3.70%–14.81% range

Source: Darul Halal Farms Health Records, 2024. GI = Gastrointestinal. Orf = Contagious Ecthyma.

3. Disease Frequency and Co-occurrence

Among the diseases recorded, conjunctivitis and enteritis were the most frequently observed, appearing in seven and seven recording events, respectively, suggesting persistent environmental or management-related stressors. Foot rot was recorded on five occasions, and contagious ecthyma (Orf) on four occasions. Traumatic injuries occurred on three dates, and pneumonia was documented on two separate dates. Mastitis and miscarriage were each recorded once. Multi-system disease co-occurrence — such as conjunctivitis combined with Orf and enteritis, and foot rot combined with diarrhoea and conjunctivitis — was observed on multiple dates, indicating complex pathological interactions within the flock.

4. Morbidity Peaks and Seasonal Patterns

The highest single-event morbidity (14.81%; 4 deaths) occurred on 06/10/2024 and was entirely attributable to a foot rot outbreak. Additional morbidity peaks of 11.11% (3 deaths each) were recorded on 05/10/2024 (traumatic injury + enteritis), 12/10/2024 (mastitis + foot rot + pneumonia), and 01/11/2024 (conjunctivitis + Orf), indicating a period of heightened disease burden in October, potentially linked to seasonal climatic transitions and increased pathogen circulation.

Discussion

The 27 mortalities recorded over the three-month study period underscore the considerable burden of disease in the study flock and reflect a pattern consistent with small ruminant health challenges documented across sub-Saharan Africa. The daily mortality ranged from 1 to 4 animals, with morbidity rates between 3.70% and 14.81%, highlighting the acute nature of the disease events experienced by the flock.

The persistent presence of conjunctivitis across multiple recording dates suggests exposure to persistent environmental irritants or pathogens, such as Moraxella ovis or Mycoplasma spp., often exacerbated by dusty conditions, overcrowding, and poor ventilation (Adebayo *et al*., 2021; Rahman *et al*., 2022) [3, 17]. These findings align with reports from northern Nigeria, where semi-arid conditions, high dust loads, and intensive stocking densities predispose small ruminants to ocular disease.

Enteritis, which occurred on seven occasions and contributed significantly to cumulative mortality, is a well recognised cause of goat mortality under suboptimal hygiene and feeding conditions. The condition can be precipitated by bacterial pathogens (Escherichia coli, Salmonella spp., Clostridium perfringens), viral agents, or gastrointestinal parasites. The recurring nature of enteric disease in this flock aligns with findings by Uma *et al*. (2023) [20], who identified gastrointestinal infections as major contributors to goat mortality in smallholder systems, particularly where water and feed hygiene are inadequate.

Foot rot, caused predominantly by Dichelobacter nodosus and Fusobacterium necrophorum, was the condition associated with the highest morbidity event (14.81% on 06/10/2024). This contagious disease is typically exacerbated by wet, muddy conditions and high stocking densities. Its occurrence in October may reflect the transition from the rainy to the dry season in northern Nigeria, a period characterised by softened hooves and increased inter-animal contact (Hassan *et al*., 2021) [7].

Contagious ecthyma (Orf), a zoonotic poxviral disease, was recorded on four occasions. Its repeated occurrence indicates insufficient vaccination coverage and likely persistence of the virus in the environment. Given its zoonotic potential, this disease has particular public health implications and should be addressed through a coordinated vaccination programme (Khalid *et al*., 2022) [8].

The multi-system disease presentations — such as concurrent conjunctivitis, Orf, and enteritis, or foot rot combined with pneumonia and mastitis — suggest a background of compromised host immunity, likely driven by nutritional deficiencies, overcrowding-related stress, and a high cumulative pathogen load. This pattern aligns with the concept of immunosuppression-mediated poly-pathology in production animals under intensive management (Musa *et al*., 2023) [11].

Traumatic injuries, recorded on three dates and contributing to 5 mortalities, point to management-related deficiencies, such as inadequate housing design, sharp protrusions in pens, or aggressive inter-animal interactions. These preventable causes of mortality can be addressed through simple husbandry improvements.

The miscarriage recorded on 15/09/2024, resulting in two deaths, warrants particular attention in a breeding herd. Reproductive losses in goats may be attributable to nutritional deficiencies (particularly selenium, copper, and vitamin E), infectious causes (Brucella spp., Chlamydophila abortus, Toxoplasma gondii), or management-related stress (Adamu *et al*., 2022) [1]. Without further diagnostic work-up, the aetiology in this case remains unclear, though the temporal proximity to multiple concurrent disease events suggests that stress or infectious agents may have played a role.

The clustering of high-morbidity events in October likely reflects the influence of seasonal climatic variation on pathogen dynamics and host susceptibility. Similar seasonal amplification of disease burden in small ruminants has been documented in northern Nigeria and other Sahelian regions, where transitions between rainy and dry seasons alter grazing conditions, water availability, and vector populations (Uma *et al*., 2023; Olanrewaju *et al*., 2020) [15, 20].

Conclusion

This study demonstrates that goat mortality at Darul Halal Farms, Katsina, was driven by a multifactorial combination of infectious, environmental, and management-related health challenges during September–November 2024. Conjunctivitis and enteritis were the most common conditions, while foot rot accounted for the highest single-event morbidity. Multi-system disease co-occurrence, reproductive losses, and traumatic injuries further compounded the mortality burden. The temporal clustering of high-morbidity events in October suggests a seasonal dimension to disease dynamics that warrants proactive management during transition periods.

The findings highlight critical gaps in biosecurity, housing design, nutritional management, and vaccination coverage. If addressed systematically, these gaps could substantially reduce mortality and improve productivity in this and similar breeding goat operations in northern Nigeria.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. **Vaccination Programme**: A structured vaccination calendar should be implemented for contagious ecthyma, pasteurellosis (pneumonia), enterotoxaemia, and other endemic diseases. Vaccination coverage should be reviewed and updated at least twice yearly, with particular attention to the pre-October period to pre-empt seasonal disease amplification.

2. **Parasite Control:** A strategic anthelmintic deworming programme should be introduced, guided by faecal egg counts, to reduce the burden of gastrointestinal parasitism. Rotational grazing should be practised to minimise pasture contamination with infective larvae.

3. **Housing and Sanitation:** Pens should be redesigned to remove sharp protrusions and reduce overcrowding. Regular cleaning and disinfection protocols should be established to reduce pathogen loads, particularly for enteric and respiratory pathogens.

4. **Nutritional Management:** A nutritional assessment of the herd should be conducted, with particular attention to protein, energy, vitamin, and trace mineral adequacy. Supplementation programmes should be designed and implemented, especially for breeding does during the

periparturient period, to reduce the risk of miscarriage and support neonatal survival.

5. **Veterinary Surveillance:** Regular herd health monitoring by qualified veterinary personnel should be implemented. This should include routine clinical examinations, targeted laboratory diagnostics, and timely treatment protocols to contain disease outbreaks before they escalate.

6. **Record-Keeping Enhancement:** The farm should improve its health records to capture individual animal identification, breed, age, parity, weight, and detailed treatment history. This will enable more rigorous survival analysis and evidence-based herd management.

7. **Zoonotic Disease Awareness:** Given the presence of contagious ecthyma (Orf) — a zoonotic disease — farm workers should be educated on personal protective practices when handling infected animals. Regular sensitisation on brucellosis and other zoonoses should also be provided.

8. **Further Research:** Future studies should use larger sample sizes, individual animal tracking, and molecular characterisation of causative pathogens to strengthen the evidence base for preventing goat mortality in northern Nigeria.

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