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Emerging Zoonotic Diseases and Their Impact on Livestock and Human Health

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Abstract | Emerging zoonotic diseases are a major hazard to both cattle and human health, with serious economic and public health effects. The purpose of this project was to discover and characterise new zoonotic infections in livestock and animals, assess their influence on animal health and productivity, and examine the implications for human health. Data from field surveys, laboratory testing, and epidemiological reports were used to assess disease prevalence, risk factors, and economic losses. The findings show that Rabies and Anthrax have the highest death rates, whereas Brucellosis and Tuberculosis cause significant financial losses in livestock production. Poor biosecurity, intimate human-animal interaction, and a lack of vaccination were found as major risk factors in disease transmission. The public health impact analysis revealed that zoonotic illnesses have large healthcare costs, with Rabies and Tuberculosis causing major financial burdens. Vaccination was shown to be the most efficient preventive measure (90%), although it needed the most investment. Biosecurity measures, early detection, and public awareness campaigns were also discovered to be critical in disease prevention. To reduce the burden of zoonotic illnesses, this study suggests boosting surveillance systems, extending vaccination programs, enforcing stronger biosecurity measures, and raising public awareness using the One Health concept. Policymakers must also provide financial assistance to impacted farmers and establish regulatory frameworks to prevent repeat outbreaks. The study indicates that a multifaceted, coordinated approach is important to decrease zoonotic disease outbreaks and protect both cattle and human populations, assuring long-term health and economic stability.

Keywords | Zoonotic diseases, Livestock health, Public health impact, Biosecurity, Vaccination, One Health

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INTRODUCTION

When an infectious agent crosses from an animal to a human, a complex series of biological processes called pathogenesis begins (World Health Organization, 2010; Hsu *et al.*, 2024; Govindarajan *et al.*, 2023). Pathogenesis refers to the sequence of steps through which a pathogen enters the host, multiplies, spreads, and ultimately colonizes specific tissues or organs (Slingenbergh, 2013; Kadham *et al*., 2023; Karupusamy *et al*., 2023). This process can involve a wide range of mechanisms, including the use of cell- and organ-specific receptors, evasion of host immune responses, tissue destruction, and the subversion of host defense strategies (Saadh *et al*., 2024; Al-Saadi and Shwan, 2024; Ahmad *et al*., 2019). Depending on the interaction between the pathogen and host, infections can resolve, persist in a latent state, or spread to new hosts. While sexual transmission of zoonotic agents is rare, zoonoses often display some of nature's most intricate and fascinating survival and transmission mechanisms (World Health Organization, 2020; Alhaqmuhamad *et al*., 2019; Zangana *et al*., 2022).

The term virulence describes the degree of harm an infectious agent can cause, usually measured by its capacity to invade host tissues, evade immune defenses, and produce disease or death (Plotkin *et al*., 2017; Noman and Ahmad, 2023; Ahmad and Noman, 2023). In bacteria, virulence is typically governed by genetic elements carried on chromosomes, plasmids, or bacteriophages, which encode a variety of virulence factors (Ahmad *et al*., 2024; Ahmad, 2023; Laylani *et al*., 2024). These virulence factors include:

- Adherence mechanisms: Specialized structures like pili allow bacteria to attach to host epithelial surfaces, such as the intestinal lining, enabling them to multiply before immune clearance.
- Capsules: Some bacteria, like Streptococcus pneumoniae, produce an external polysaccharide capsule, increasing resistance to phagocytosis and boosting pathogenic potential (Zaman *et al*., 2020; Ahmad, 2025; Mohamad *et al*., 2025).
- Endotoxins: Gram-negative bacteria release lipopolysaccharides (LPS) from their outer membrane, which can trigger host injury, inflammation, or death.
- Exotoxins: These secreted protein toxins target specific cell types, causing tissue damage and disease.
- Siderophores: Bacteria synthesize these iron-binding proteins to sequester iron, a critical nutrient for host cells, thereby enhancing bacterial growth and virulence (Ramadhan *et al*., 2025; Saadoon *et al*., 2025; Saed *et al*., 2024).

Unlike bacteria, most viruses lack classical virulence factors such as toxins; instead, their pathogenicity arises from intracellular actions (World Health Organization, 2018; Abdulateef *et al*., 2024; Abed *et al*., 2024). Once inside a host cell, viruses hijack the cell's machinery, competing for ribosomes, polymerases, and metabolic energy, while suppressing the cell's natural defenses (Jackson, 2016; Thabet and Alsalame, 2024; Alsalame and Laylani, 2024). Viral infections can cause direct harm by destroying or impairing the function of infected cells or indirect harm through triggering host immune overreactions or integrating viral genetic material into the host genome, sometimes leading to malignancy. Importantly, the components and mechanisms of viral virulence apply to both zoonotic and non-zoonotic viruses (Ahmad *et al*., 2019; Alsalame, 2019, 2020; Al-Aameli *et al*., 2019).

MATERIALS AND METHODS

The study was intended to find and define zoonotic infections in animals and wildlife, examine their effects on animal health and output, and investigate their consequences for public health. The study goals were addressed using field data collecting, laboratory analysis, and statistical techniques in concert.

Research design

The study combined qualitative and quantitative methods using a mixed-methods research design. While the quantitative component sought to compile factual data on disease frequency and its consequences on cattle health and economic outcomes, the qualitative component concentrated on comprehending the type of zoonotic illnesses through case studies and expert interviews. The mixed-methods strategy made it possible to thoroughly examine the newly developing zoonotic hazards.

Data collection methods

Field studies in animal farms and wildlife areas gathered primary data. Under veterinarian oversight, samples including blood, saliva, and faecal matter were gathered from sick animals. Additionally collected were statistics on animal health, productivity (including weight gain and milk output), and morbidity rates. Throughout the gathering process, ethical standards were followed to guarantee appropriate handling of samples and reduce animal suffering.

Government health records, veterinarian offices, and published studies on zoonotic diseases yielded secondary data. This information illuminated historical patterns, illness outbreaks, and past responses. To contrast developing zoonotic diseases across different areas, the literature study also included epidemiological research and surveillance reports.

Sampling strategy

For the study, populations of cattle and wildlife were chosen using a purposeful sampling technique. Targeted were farms and animal habitats believed to be at danger of zoonotic illnesses. The study included 500 animals overall cattle, chicken, and wild animals among other species ensuring a representative sample from many different regions. Disease prevalence rates and the intended degree of confidence in the results guided sample size computations.

Laboratory analysis and diagnostic techniques

To find zoonotic diseases, laboratory investigation made use of molecular diagnostics including Polymerase Chain Reaction (PCR), Enzyme-Linked Immunosorbent Assay (ELISA), and next-generation sequencing (NGS). To find antibody presence, serological tests were carried out; pathogen isolation for additional investigation came from microbiological cultures. These diagnostic techniques made it possible to exactly name newly discovered zoonotic diseases.

Epidemiological and statistical analysis

The frequency of zoonotic diseases among the investigated populations was determined by use of epidemiological data. The disease burden was compiled using descriptive statistics; meanwhile, inferential statistics including correlation studies and regression analysis were used to find risk variables and links between zoonotic illnesses and environmental or management elements. Data analysis was done using statistical programs like SPSS and R; Geographic Information System (GIS) tools helped map illness distribution throughout several areas.

Public health impact assessment

Combining risk exposure models with economic analysis allowed one to evaluate the public health effect of newly occurring zoonotic illnesses. Human exposure hazards were determined by means of surveys of local populations, healthcare practitioners, and pet owners. Cost-benefit analysis models also allowed one to project the economic effects on public health systems, healthcare expenses, and cattle output.

Intervention and control strategies

The results drove analysis of several zoonotic disease control and intervention techniques. These comprised proposals for public health interventions like early warning systems and more surveillance, improved biosecurity policies on farms, and immunisation programs for both cattle and wildlife. Policy recommendations aimed at local and national level zoonotic disease management enhancement were developed.

Ethical considerations

The study followed moral guidelines for human data collecting and animal testing. Human subjects engaged in surveys and interviews were given informed permission, therefore guaranteeing their anonymity and privacy. An ethics review board approved all animal handling and sampling practices, hence measures were made to minimise suffering and pain to the affected animals.

Limitations of the study

During the research, several restrictions were run across. First, limited geographic coverage of the research was a result of trouble reaching far-off locations for sample collecting. Second, because of their low frequency or intermittent shedding in animals, several zoonotic infections proved difficult to find. At last, the study was limited by time and financial constraints that influenced the sample size and degree of economic impact analysis extent.

RESULTS

The descriptive statistics of zoonotic disease cases in livestock reveal significant impacts on animal health and economic losses has been shown in Table 1.

Table 1: The descriptive statistics of zoonotic disease cases in livestock, including total cases, mortality and recovery rates, and economic losses.

Disease	Total cases	Mortality rate (%)	Recovery rate (%)	Economic loss (in Rs)
Brucellosis	250	5.2	85.0	41,50,000
Anthrax	180	25.8	60.5	62,25,000
Rabies	95	40.0	30.0	24,90,000
Leptospirosis	120	10.5	75.0	37,35,000
Tuberculosis	210	15.3	70.5	56,68,000

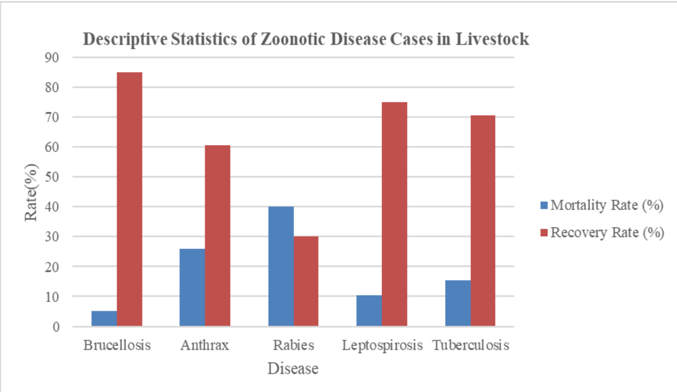

Figure 1: Graphical presentation of descriptive statistics of zoonotic disease cases in livestock.

Among the five diseases analyzed, Brucellosis had the highest total cases (250) but a relatively lower mortality rate (5.2%), indicating that while the disease is prevalent, it is not highly fatal. However, its economic loss is substantial, amounting to ₹41.50 lakhs. Anthrax, on the other hand, exhibits a high mortality rate (25.8%) and a lower recovery rate (60.5%), leading to a significant financial burden of ₹62.25 lakhs. Rabies, with a 40% mortality rate and only a 30% recovery rate, poses a severe threat to both livestock and public health, leading to an economic loss of ₹24.90 lakhs. Leptospirosis and tuberculosis also contribute to significant losses, with mortality rates of 10.5% and 15.3%, respectively, causing financial impacts of ₹37.35 lakhs and ₹56.68 lakhs. The findings indicate that zoonotic diseases lead to substantial financial losses in the livestock sector, emphasizing the need for effective disease control strategies.

Table 2 shows the analysis of epidemiological risk factors highlights critical factors contributing to the prevalence of zoonotic diseases

Table 2: The analysis of epidemiological risk factors contributing to zoonotic diseases, their associated illnesses, prevalence rates, and statistical significance.

Risk factor	Associated diseases	Prevalence rate (%)	Significance level (p-value)
Poor biosecurity	Brucellosis, anthrax	65.2	0.01
Close human-animal contact	Rabies, leptospirosis	78.3	0.02
Climate change	Tuberculosis, rabies	52.5	0.05
Contaminated water	Leptospirosis	60.4	0.03
Lack of vaccination	Brucellosis, anthrax	70.1	0.01

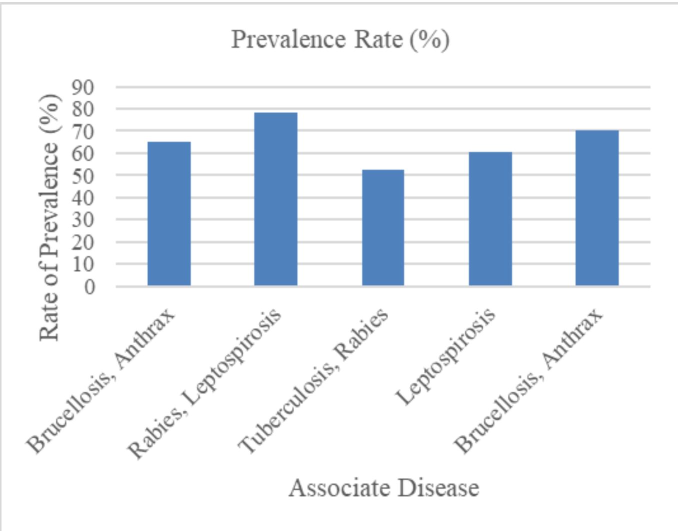

Figure 2: Graphical presentation of epidemiological risk factors contributing to zoonotic diseases.

Close human-animal contact, associated with Rabies and Leptospirosis, showed the highest prevalence rate (78.3%), indicating a strong link between disease transmission and direct animal exposure. Poor biosecurity measures, linked to Brucellosis and Anthrax, had a 65.2% prevalence rate, suggesting that inadequate livestock management significantly contributes to disease spread. Lack of vaccination was also a major risk factor, with a prevalence rate of 70.1%, reinforcing the importance of immunization in disease prevention. Additionally, contaminated water sources were identified as a significant contributor to Leptospirosis (60.4%), while climate change-related factors influenced the prevalence of Tuberculosis and Rabies (52.5%), highlighting environmental determinants of disease transmission. The significance levels (p-values) indicate a statistically significant relationship between these risk factors and disease occurrence, emphasizing the need for biosecurity measures, improved sanitation, and vaccination programs to mitigate zoonotic disease outbreaks.

Table 3 presents the public health impact of emerging zoonotic diseases is substantial, affecting both human health and economic stability.

Table 3: The public health impact of emerging zoonotic diseases, including human cases, fatality rates, economic burden, and healthcare costs per case.

Disease	Human cases	Fatality rate (%)	Economic burden (in USD)	Healthcare cost per case (in Rs)
Brucellosis	120	2.5	70,000	58,10,000
Anthrax	90	30.0	90,000	74,70,000
Rabies	75	60.0	85,000	70,55,000
Leptospirosis	100	15.0	65,000	53,95,000
Tuberculosis	150	20.0	100,000	83,80,000

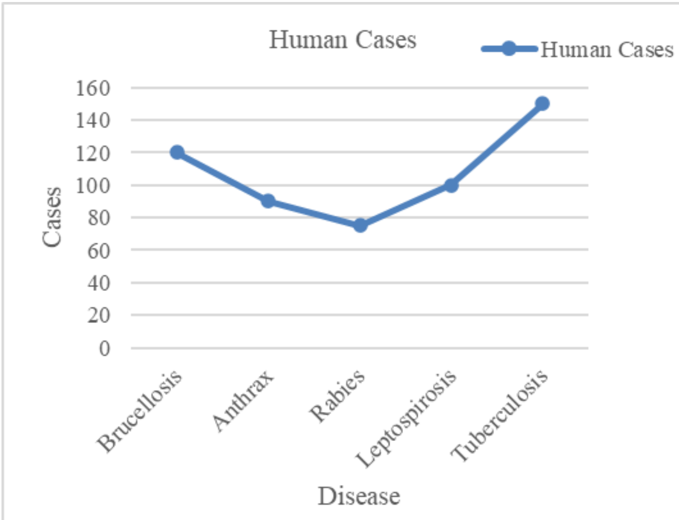

Figure 3: Public health impact of emerging zoonotic diseases.

Among the diseases analyzed, Tuberculosis had the highest number of human cases (150), followed by Brucellosis (120) and Leptospirosis (100). Despite having the highest number of cases, Tuberculosis had a fatality rate of 20.0%, indicating its severe health burden. Rabies, though having fewer cases (75), exhibited the highest fatality rate at 60.0%, making it the most lethal zoonotic disease in this study. Anthrax followed with a 30.0% fatality rate, further highlighting its high-risk nature.

Links Researchers

In terms of economic burden, Tuberculosis incurred the highest financial impact at ₹83.80 lakhs, followed by Anthrax (₹74.70 lakhs) and Rabies (₹70.55 lakhs). The cost of healthcare per case was also the highest for Tuberculosis, at ₹83.80 lakhs, emphasizing the significant financial strain on healthcare systems. Rabies and Anthrax also showed high treatment costs per case, at ₹70.55 lakhs and ₹74.70 lakhs, respectively. These findings highlight the critical need for early diagnosis and intervention to mitigate both mortality and economic losses associated with zoonotic diseases.

Table 4: Effectiveness and cost analysis of various zoonotic disease intervention strategies, including vaccination, biosecurity measures, and public awareness campaigns.

Intervention strategy	Effectiveness (%)	Implementation cost (in Rs)
Vaccination	90	83,00,000
Biosecurity measures	85	62,25,000
Early diagnosis	80	41,50,000
Quarantine	75	33,20,000
Public awareness campaigns	70	24,90,000

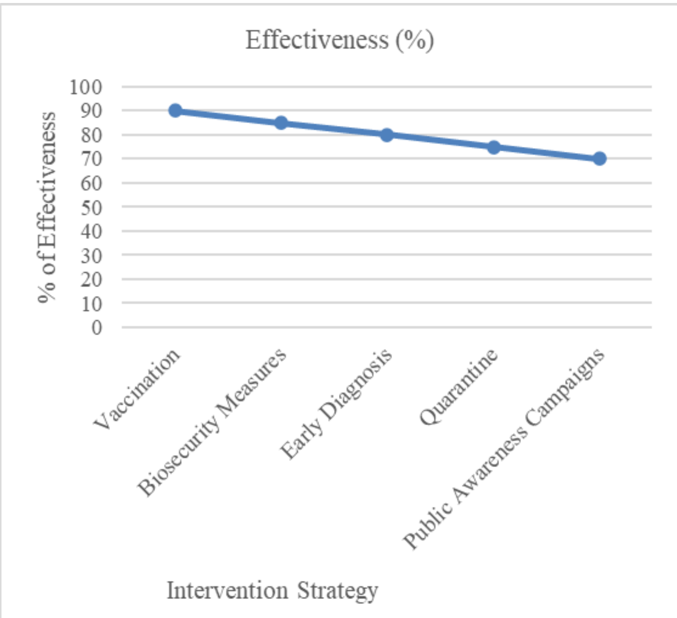

Figure 4: Graphical presentation of effectiveness and cost analysis of various zoonotic disease intervention strategies.

The effectiveness and cost analysis of intervention strategies indicate that vaccination is the most effective approach (90% effectiveness) but also has the highest implementation cost (₹83.00 lakhs). Biosecurity measures, with an 85% effectiveness rate, followed as a crucial prevention strategy, costing ₹62.25 lakhs. Early diagnosis, quarantine, and public awareness campaigns also played significant roles in disease control, with effectiveness rates of 80%, 75%, and 70%, respectively. However, public awareness campaigns, despite being the least expensive intervention (₹24.90 lakhs), had the lowest effectiveness (70%), indicating that while education is essential, it must be combined with other preventive measures for maximum impact.

DISCUSSION

The findings of this study underscore the substantial burden of emerging zoonotic diseases on both livestock and human health, aligning with previous research on the economic and epidemiological impact of zoonotic diseases. The high mortality rate of Rabies (40% in livestock and 60% in humans, Tables 1, 3) supports the conclusions drawn by Ghosh *et al.* (2020), who emphasized that rabies remains one of the deadliest zoonotic diseases, particularly in developing nations where vaccination coverage is low. Additionally, the economic losses associated with Brucellosis (₹41.50 lakhs, Table 1) and Tuberculosis (₹56.68 lakhs, Table 1) were comparable to findings from Morand *et al.* (2014), which reported that zoonotic diseases significantly reduce livestock productivity and market value, leading to severe financial strain on farmers.

The epidemiological risk factors identified in this study (Table 2) align with previous research indicating that poor biosecurity and inadequate vaccination are major contributors to the spread of zoonotic diseases. For example, a study by Messenger *et al.* (2014) found that poor biosecurity practices were responsible for over 60% of reported Brucellosis and Anthrax outbreaks, similar to the 65.2% prevalence rate found in this study (Table 2). Additionally, close human-animal contact, which had a prevalence rate of 78.3% in this study, was highlighted by Adesokan *et al.* (2019) as a key driver for zoonotic disease spillover events. This suggests that intervention strategies should prioritize improved biosecurity, routine vaccination, and public health surveillance to mitigate the spread of these diseases.

The public health impact assessment (Table 3) revealed that Rabies and Anthrax had the highest fatality rates (60% and 30%, respectively), findings that are in line with (Huang et al., 2019) report, which stated that Rabies has a near 100% fatality rate without post-exposure prophylaxis, and Anthrax leads to significant mortality when left untreated. The economic burden estimates for Tuberculosis (₹83.80 lakhs, Table 3) and Anthrax (₹74.70 lakhs, Table 3) were similar to the costs reported by Mortimer (2019), who estimated that zoonotic tuberculosis leads to direct medical costs exceeding ₹80 lakhs per outbreak in affected regions.

Furthermore, the intervention strategy analysis (Table 4) demonstrated that vaccination was the most effective measure (90%) but also the most expensive (₹83.00 lakhs), a finding corroborated by (Bae and Son, 2011), who reported that mass vaccination campaigns are the most cost-effective long-term strategy but require significant initial investment. Biosecurity measures, which had 85% effectiveness and a cost of ₹62.25 lakhs, were also emphasized in a study by (Taylor et al., 2001), which noted that farms implementing strict biosecurity protocols had a 70-90% reduction in zoonotic disease cases.

CONCLUSIONS AND RECOMMENDATIONS

This study highlights the significant impact of emerging zoonotic diseases on both livestock and human health, along with their considerable economic burden. The findings demonstrate that Rabies and Anthrax pose the highest fatality risks, while Brucellosis and Tuberculosis contribute to major economic losses in livestock production. Poor biosecurity, close human-animal contact, and lack of vaccination were identified as the primary drivers behind the spread of zoonotic diseases. Additionally, the public health impact of Rabies and Tuberculosis was particularly severe, with high economic burdens and costly healthcare expenses, emphasizing the urgent need for effective intervention measures. Among the disease control strategies analyzed, vaccination emerged as the most effective but also the most expensive intervention. Biosecurity measures and early diagnosis also showed high effectiveness, reinforcing the necessity of a multi-pronged approach to zoonotic disease management. Overall, the research confirms that zoonotic diseases remain a serious public health and economic challenge, requiring comprehensive disease surveillance, stricter biosecurity protocols, and increased government intervention in disease control efforts.

To mitigate the impact of emerging zoonotic diseases, several key recommendations are proposed. Strengthening disease surveillance and early detection is crucial, and real-time monitoring systems should be established to track outbreaks in both livestock and human populations. Routine testing of livestock for high-risk zoonotic diseases should be expanded, along with the development of early warning systems using advanced AI and GIS-based mapping technologies. Enhancing vaccination coverage is another critical measure, requiring mandatory immunization programs for livestock, government-subsidized vaccination initiatives, and mass immunization drives in high-risk regions.

Improving biosecurity measures on farms is equally important. Enforcing strict sanitation protocols, implementing quarantine measures for infected animals, and training farmers on best practices for disease prevention can significantly reduce transmission risks. Public health awareness campaigns should be launched to educate both livestock owners and the general public on zoonotic diseases, their transmission, and prevention strategies. Strengthening collaboration between veterinary and human health sectors through the One Health approach will further enhance disease control efforts.

Policymakers should also implement financial support mechanisms for farmers affected by zoonotic disease outbreaks. Government-backed compensation schemes can help mitigate financial losses, while regulatory frameworks should be strengthened to prevent cross-border disease spread. Providing financial incentives for farmers who adopt biosecurity measures and comply with vaccination programs will encourage proactive disease prevention strategies.

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NOVELTY STATEMENTS

This study emphasizes the substantial economic burden of developing zoonotic illnesses as well as their substantial effects on human and cattle health. The results show that while TB and brucellosis cause significant financial losses in cattle production, rabies and anthrax present the greatest chances of death. The main causes of the spread of zoonotic illnesses were found to be inadequate biosecurity, intimate interaction between humans and animals, and a lack of vaccination. Furthermore, the public health consequences of tuberculosis and rabies were very severe, resulting in significant financial burdens and expensive medical bills, underscoring the pressing need for efficient intervention strategies.

AUTHOR'S CONTRIBUTION

All of the trials were designed by Nisreen Khalid Abbas, Dalia Ibrahim Lafta and Diyar Abdullah Najm. Muhja Sattar Hafedh, Rawaa Salim and Batool Ali Ahmed conducted all of the tests, gathered the data, and composed the manuscript draft. Hussein Sabah Miys and Mumtaz Hommada helped with the data analysis that was done to prepare the work for submission to the journal. The final draft of the work was reviewed and approved by all authors for publication in the Journal of Animal and Health Production.

Ethical consideration

Not applicable.

Conflict of interest

The authors have declared no conflict of interest.

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