ABSTRACT

Stability and Bifurcation Analysis of a Bird Flu Model with Vaccination in a Poultry Farm

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This study develops and analyzes deterministic compartmental models to investigate the transmission dynamics of avian influenza in a poultry farm under two scenarios: without vaccination and with vaccination. The models incorporate key epidemiological processes, including recruitment, natural mortality, disease-induced mortality, transmission, and removal, and are formulated as systems of nonlinear ordinary differential equations. The basic reproduction number, R_0, and the effective reproduction number under vaccination, R_v, are derived to characterize disease transmission. Analytical techniques, including equilibrium analysis and Jacobian-based linearization, are employed to examine the local stability of both disease-free and endemic equilibria. The analysis reveals that the system exhibits a forward transcritical bifurcation at the threshold $R_0 = 1$, which determines whether the disease dies out or persists endemically. In the presence of vaccination, the threshold condition is modified to $R_v = (1-\rho)R_0$, indicating that vaccination reduces the effective transmission

rate. The results show that the disease can be eliminated when vaccination coverage exceeds a critical level. Numerical simulations are conducted to support the analytical findings and to illustrate the qualitative behavior of the system. Overall, the results emphasize the significant role of vaccination and transmission control in mitigating outbreaks. This study provides a mathematically rigorous framework and practical insights for designing effective disease control strategies in poultry farm management.

Keywords: Bird Flu, Stability Analysis, Bifurcation, Numerical Results