

Case Study of Successful Eradication of Newcastle Disease in Chicken Populations via Vaccination

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Abstract This study aims to examine the successful eradication of ND in chicken populations through vaccination, focusing on a specific case study of a region that overcame major outbreaks via an organized vaccination campaign. The study details the etiology and pathogenesis of the Newcastle disease virus (NDV), clinical signs, and diagnosis in chickens, as well as the global epidemiology of ND. It further evaluates the different types of vaccines, including live, inactivated, and recombinant vaccines, alongside challenges in vaccine development. The case study explores the initial ND outbreaks, the methods of vaccination implementation, and the factors contributing to the success of the vaccination program, such as effective delivery systems, government support, and public awareness. Key challenges faced during the campaign, such as logistical issues and vaccine hesitancy, are also discussed. Post-vaccination surveillance, long-term monitoring, and strategies for preventing disease resurgence are highlighted, along with policy implications for expanding vaccination efforts globally. The paper concludes by emphasizing the critical role of vaccination in controlling ND and providing recommendations for future disease eradication efforts.

Keywords Newcastle disease; Vaccination campaign; Poultry; Vaccine development; Disease eradication

1 Introduction

Newcastle disease (ND) is a highly contagious viral disease affecting a wide range of avian species, particularly chickens. It is caused by the Newcastle disease virus (NDV), which can lead to severe respiratory, nervous, and digestive symptoms in infected birds. The disease is known for its rapid spread and high mortality rates, especially in unvaccinated flocks, making it a significant concern for poultry farmers worldwide (Hu et al., 2017; Tian et al., 2020). NDV can cause up to 100% morbidity and mortality in chickens, highlighting the critical need for effective control measures (Ding et al., 2019).

The poultry industry is a vital component of the global agricultural economy, and Newcastle disease poses a substantial threat to its sustainability. ND outbreaks can lead to devastating economic losses due to high mortality rates, decreased egg production, and trade restrictions (Tian et al., 2020; Shi et al., 2024). The disease is particularly challenging in developing countries, where resources for disease management may be limited. Vaccination is the most effective strategy to prevent and control ND outbreaks, and various vaccine types, including live attenuated and recombinant vaccines, have been developed to protect poultry populations (Said et al., 2019; Ferreira et al., 2020).

This study attempts to explore the successful eradication of Newcastle disease in chicken populations through vaccination, discuss the efficacy of different vaccination strategies, and provide an overview of their impact on controlling ND outbreaks. By analyzing the outcomes of various vaccination programs, the study aims to offer insights into best practices for ND management and contribute to the development of more effective vaccination protocols in the poultry industry. The ultimate goal is to enhance the understanding of ND control measures and support global efforts to safeguard poultry health and productivity.

2 Background of Newcastle Disease (ND)

Newcastle disease (ND) is a highly contagious viral disease that affects a wide range of avian species, both domestic and wild. It poses significant economic challenges to the poultry industry worldwide due to its high

morbidity and mortality rates (Abdisa and Tagesu, 2017; Sahoo et al., 2022). The disease is caused by the Newcastle disease virus (NDV), which belongs to the genus Avulavirus, sub-family Paramyxovirinae, and family Paramyxoviridae.

2.1 Etiology and pathogenesis of ndv (Newcastle disease virus)

NDV is classified into different pathotypes based on its virulence: asymptomatic enteric, lentogenic, mesogenic, viscerotropic velogenic, and neurotropic velogenic strains (Abdisa and Tagesu, 2017). The virus primarily spreads through respiratory aerosols, fecal contamination, and contact with infected birds or contaminated materials. Pathogenesis studies have shown that NDV can infect various tissues, including the respiratory and gastrointestinal tracts, and can cause systemic infections leading to severe clinical signs and high mortality. The virus's ability to replicate in multiple organs, such as the trachea, liver, spleen, and brain, contributes to its pathogenicity (Hussein et al., 2019; Akanbi et al., 2020).

2.2 Clinical signs and diagnosis of ND in chickens

Clinical signs of ND in chickens vary depending on the virus strain, age, and species of the bird, as well as the presence of concurrent infections and immunity levels. Common symptoms include respiratory distress (gasping, coughing, sneezing), neurological signs (tremors, paralysis, twisted necks), and gastrointestinal issues (greenish diarrhea). Diagnosis is typically based on clinical signs, history, and laboratory confirmation through virus isolation, serological tests, and molecular techniques such as RT-PCR (Abdisa and Tagesu, 2017; Nyoman et al., 2024).

2.3 Epidemiology and global distribution of ND

ND is endemic in many parts of the world, including Asia, Africa, and some regions of the Americas, while countries like the United States and Canada are free from virulent strains in poultry (Abdisa and Tagesu, 2017). The disease's prevalence varies significantly across different regions and is influenced by factors such as bird species, management practices, and environmental conditions (Zegeye et al., 2021; Sahoo et al., 2022). In Ethiopia, for example, the seroprevalence of ND in chickens was estimated to be around 21.47%, highlighting the need for effective control measures⁴. Similarly, in Bangladesh, outbreaks of ND caused by genotype VII (Hussein et al., 2019) have been reported, indicating the virus's widespread distribution and the challenges in controlling its spread (Figure 1) (Nooruzzaman et al., 2022). Newcastle disease remains a significant threat to poultry health globally, with its complex etiology, diverse clinical manifestations, and widespread distribution necessitating comprehensive control strategies, including vaccination and biosecurity measures.

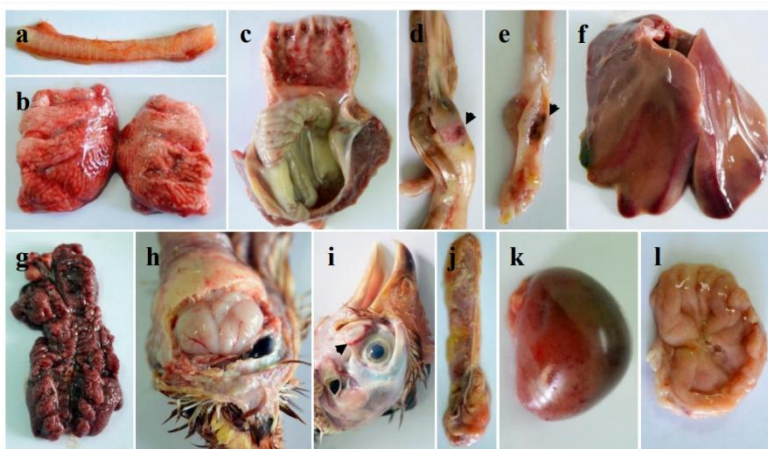


Figure 1 Gross pathological changes in chickens experimentally inoculated with LT67 isolates of NDV (Adopted from Nooruzzaman et al., 2022)

Image caption: (a) Hemorrhages in the trachea, (b) congestion in the lungs, (c) hemorrhages in the proventriculus, (d) hemorrhages in the intestines (button-like ulcers), (e) C hemorrhages in the cecal tonsils, (f) congestion in the liver, (g) severe congestion in the kidneys, (h) congestion in the brain, (i) hemorrhages in the Harderian glands, (j) hemorrhages and atrophy in the thymus, (k) congestion in the spleen, and (l) hemorrhages and slight atrophy in the bursa of Fabricius (Adopted from Nooruzzaman et al., 2022)

3 Vaccine Development and Types

3.1 Overview of vaccines for Newcastle disease

Newcastle disease (ND) is a significant threat to poultry, necessitating effective vaccination strategies. Vaccines for ND have been developed over the past 60 years, with a focus on preventing the replication and infection of the Newcastle disease virus (NDV) (Shafaati et al., 2024). The World Organisation for Animal Health emphasizes the importance of ND vaccination due to its economic impact and rapid spread potential. Traditional vaccines include live and inactivated forms, which have been widely used since the 1950s. Recent advancements have introduced recombinant and viral-vectored vaccines, which express NDV proteins to enhance immune responses (Figure 2) (Dimitrov et al., 2016; Fulber and Kamen, 2022).

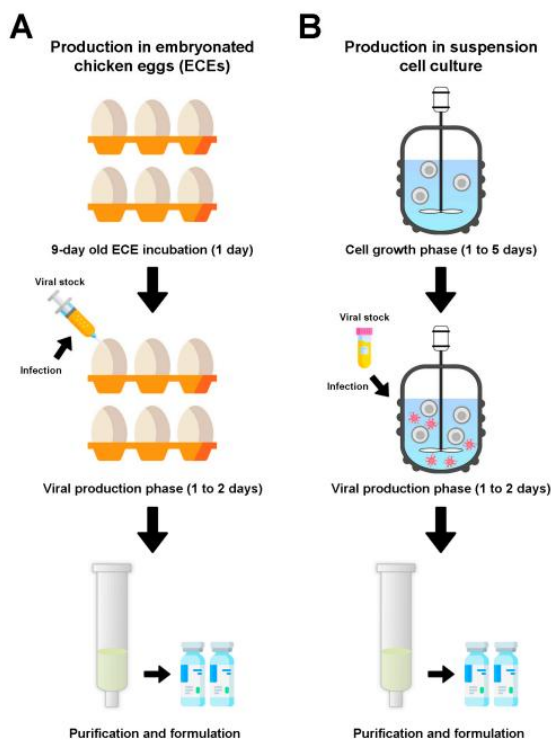


Figure 2 Overview of production processes for viral-vectored vaccines in (A) embryonated chicken eggs (ECEs) and (B) suspension cell cultures in stirred-tank bioreactors (Adopted from Fulber and Kamen, 2022)

3.2 Types of NDV vaccines: live, inactivated, and recombinant

NDV vaccines are categorized into live, inactivated, and recombinant types. Live vaccines, such as the LaSota and B1 strains, are known for their efficacy and safety in both avian and non-avian species⁶. Inactivated vaccines are often used in combination with live vaccines to boost immunity. Recombinant vaccines, including those based on genotype VII.1.1, have shown superior protection by closely matching circulating field isolates (Dewidar et al., 2022). These recombinant vaccines can be engineered to express multiple antigens, providing broader protection against various NDV strains (Xu et al., 2020; Jamil et al., 2022).

3.3 Efficacy, safety, and challenges in vaccine development

The efficacy of NDV vaccines varies depending on the type and genetic match to circulating strains. Recombinant vaccines, particularly those using the VG/GA strain backbone, have demonstrated high efficacy and reduced virus shedding (Dewidar et al., 2022). Safety is a critical consideration, with avirulent strains like LaSota being preferred for their established safety profiles (Kim and Samal, 2016). However, challenges remain, such as ensuring even vaccine application in large flocks and maintaining the cold chain for thermo-labile vaccines. Additionally, maternal antibodies can interfere with vaccine efficacy, necessitating strategies to overcome this obstacle (Dimitrov et al., 2016). The development of thermostable vaccines and multi-epitope constructs are promising approaches to enhance vaccine stability and immune response (Tan et al., 2020; Jamil et al., 2022).

While significant progress has been made in NDV vaccine development, ongoing research is essential to address challenges related to vaccine application, stability, and efficacy against diverse NDV strains.

4 Case Study: Successful Eradication of Newcastle Disease through Vaccination

4.1 Introduction to the case study region/area

The case study focuses on a region where Newcastle disease (ND) has historically posed significant challenges to poultry health and economic stability. In many developing countries, ND is a major cause of poultry mortality, impacting smallholder farms and commercial operations alike (Shi et al., 2024). The region selected for this case study has a diverse poultry population, including specific pathogen-free (SPF), native, and commercial chickens, which are all susceptible to ND outbreaks (Abdoshah et al., 2022). The local poultry industry is crucial for the economy, providing both nutritional and economic benefits to the community (Otiang et al., 2021).

4.2 Initial ND outbreaks and response strategies

Initial outbreaks of ND in the region were characterized by high morbidity and mortality rates, severely affecting poultry production and leading to significant economic losses (Tatár-Kis et al., 2020; Otiang et al., 2021). The response strategies initially employed included quarantine measures and culling of infected flocks, which were not sufficient to control the spread of the disease. The lack of effective vaccination programs contributed to the persistence of the virus in the poultry population (Oberländer et al., 2020; Sultan et al., 2021). The introduction of vaccination as a control measure marked a turning point in the region's response to ND, with various vaccination programs being evaluated for their efficacy in reducing transmission and mortality (Ayoub et al., 2019).

4.3 Timeline and methods of vaccination campaign implementation

The vaccination campaign was implemented in phases, beginning with the introduction of thermoresistant vaccines, which were administered to different chicken types, including SPF, native, and broiler chickens (Abdoshah et al., 2022). The campaign involved routine vaccinations every three months, using vaccines such as the I-2 NDV vaccine, which showed significant improvements in flock size and health (Otiang et al., 2021). In some areas, a single dose of recombinant vaccines, such as the rHVT-ND, was used to provide long-term protection against ND (Shi et al., 2024). The campaign also included monitoring of antibody titers to ensure adequate immunity levels were maintained across the poultry population (Taebipour et al., 2017; Oberländer et al., 2020). Over time, the vaccination efforts led to a significant reduction in ND outbreaks, with improved flock immunity and reduced virus transmission (Tatár-Kis et al., 2020; Akther and Hassan, 2022).

In summary, the successful eradication of Newcastle disease in the case study region was achieved through a comprehensive vaccination campaign that adapted to the local poultry dynamics and employed both routine and innovative vaccination strategies. This approach not only controlled the disease but also enhanced the overall health and productivity of the poultry industry in the region.

5 Factors Contributing to the Success of Vaccination Campaign

5.1 Effective vaccine delivery systems and logistics

Effective vaccine delivery systems are crucial for the success of vaccination campaigns against Newcastle disease (ND). In southeastern Kenya, a community-centered vaccine delivery model was implemented, which involved training community vaccinators to provide vaccination services. This model significantly increased vaccine uptake and reduced ND-related deaths, demonstrating the importance of accessible and efficient vaccine delivery systems (Ogolla et al., 2024). Similarly, in rural Tanzania, the use of trained community vaccinators administering thermotolerant vaccines via eyedrop was found to be effective, highlighting the role of tailored delivery methods in enhancing vaccination success (De Bruyn et al., 2017).

5.2 Government policy support and financial resources

Government policy support and financial resources are vital for sustaining vaccination campaigns. In the Democratic Republic of Congo, the establishment of a paid vaccination service for village chickens was assessed, revealing that socio-economic factors and government support play a significant role in the adoption of

vaccination programs (Lwapa et al., 2019). Additionally, the integration of community vaccinators into the formal animal health sector was recommended to ensure the sustainability and effectiveness of vaccination efforts (Ogolla et al., 2024).

5.3 Public awareness and education in poultry farming communities

Public awareness and education are essential for increasing vaccination uptake. In southeastern Kenya, structured training on chicken husbandry and ND vaccination significantly improved vaccine accessibility and uptake among smallholder chicken farmers (Ogolla et al., 2024). Similarly, in Kongo Central province, awareness-raising efforts were identified as a priority to improve vaccination service performance and increase participation among chicken keepers (Lwapa et al., 2019). These findings underscore the importance of educating poultry farming communities to enhance the success of vaccination campaigns. The successful eradication of Newcastle disease in chicken populations through vaccination is largely dependent on effective vaccine delivery systems, government support, and public education. These factors collectively contribute to increased vaccine uptake, reduced disease-related mortality, and improved overall flock health.

6 Challenges Faced During the Vaccination Campaign

6.1 Logistical and distribution issues in rural areas

One of the primary challenges in the vaccination campaign for Newcastle disease (ND) in chicken populations is the logistical and distribution issues, particularly in rural areas. The distribution of vaccines in remote and rural regions can be hindered by inadequate infrastructure, which affects the timely delivery and storage of vaccines. In Tanzania, for instance, the uptake of ND vaccination varied significantly across communities, partly due to logistical challenges in reaching remote areas (De Bruyn et al., 2017). Similarly, in Madagascar, the success of vaccination campaigns was contingent on overcoming logistical barriers to ensure consistent vaccine delivery to rural communities (Annapragada et al., 2019).

6.2 Public resistance and vaccine hesitancy

Public resistance and vaccine hesitancy also pose significant challenges to the successful eradication of ND. In many rural communities, there is a lack of awareness and understanding of the benefits of vaccination, leading to hesitancy. This hesitancy can be exacerbated by cultural beliefs and misinformation about vaccines. In Tanzania, efforts to increase vaccination uptake had to address these socio-cultural barriers to encourage participation in vaccination programs (De Bruyn et al., 2017). Additionally, in Kenya, the perception of vaccination benefits was influenced by the observed increase in flock size, which helped to mitigate some of the hesitancy (Otiang et al., 2021).

6.3 Environmental and ecological constraints on vaccine use

Environmental and ecological factors can also constrain the use of vaccines. For instance, the presence of maternally derived antibodies (MDAs) in chickens can interfere with the efficacy of certain vaccines, necessitating the development of vaccines that can overcome this challenge. In Germany, the effectiveness of ND vaccines was evaluated in the presence of MDAs, highlighting the need for vaccines that can provide protection despite these antibodies (Oberländer et al., 2020). Furthermore, the ecological conditions in rural areas, such as high temperatures, can affect the stability and efficacy of vaccines, as seen in the need for thermotolerant vaccines in Tanzania (De Bruyn et al., 2017). The successful eradication of Newcastle disease through vaccination campaigns faces several challenges, including logistical issues in rural areas, public resistance and vaccine hesitancy, and environmental constraints. Addressing these challenges requires tailored strategies that consider the unique socio-cultural and ecological contexts of each region.

7 Post-Vaccination Surveillance and Long-term Monitoring

7.1 Continuous surveillance for Newcastle disease post-vaccination

Continuous surveillance is crucial to ensure the effectiveness of vaccination programs against Newcastle disease (ND) in chicken populations. Regular monitoring of antibody titers is essential to assess the immune status of flocks and detect any potential gaps in immunity. For instance, a study in Germany evaluated antibody titers in

backyard poultry and found that a vaccination interval of twelve weeks was generally sufficient to maintain protective immunity, although regular serological testing was recommended to ensure ongoing protection⁶. Similarly, another study emphasized the importance of monitoring viral shedding and antibody levels post-vaccination to evaluate the effectiveness of different vaccination programs (Sultan et al., 2021).

7.2 Monitoring vaccine efficacy and preventing disease resurgence

Monitoring vaccine efficacy involves assessing both the humoral immune response and the reduction in disease transmission. A study demonstrated that a recombinant herpesvirus of turkey (HVT) vaccine expressing the NDV F protein provided long-term protection with a single dose, highlighting the potential for sustained immunity and reduced need for frequent revaccination (Shi et al., 2024). Additionally, the use of vector vaccines has shown promise in reducing virus transmission, as evidenced by a study where vaccinated birds exhibited significantly lower virus excretion compared to unvaccinated controls (Tatár-Kis et al., 2020). These findings underscore the importance of selecting effective vaccines and vaccination strategies to prevent disease resurgence.

7.3 Strategies for long-term NDV control and protection

Long-term control of NDV requires a comprehensive approach that includes effective vaccination strategies and regular monitoring. The development of flock immunity is critical, as demonstrated by a study that achieved high antibody titers in native chickens through routine vaccination, thereby enhancing herd immunity (Akther and Hassan, 2022). Moreover, combining vaccination with other health management practices, such as parasitocidal treatments, can further improve flock health and productivity, as shown in a study conducted in Kenya (Otiang et al., 2021). These strategies highlight the need for integrated approaches to maintain long-term protection against NDV in chicken populations. Continuous surveillance, effective vaccine monitoring, and integrated health management strategies are essential components for the successful long-term control of Newcastle disease in chicken populations. These measures help ensure sustained immunity, prevent disease resurgence, and enhance overall flock health.

8 Policy Implications and Global Strategies

8.1 International coordination and global disease control initiatives

The eradication of Newcastle disease (ND) in chicken populations requires robust international coordination and global disease control initiatives. The World Organization for Animal Health (WOAH) emphasizes the importance of rapid notification and response to ND outbreaks due to its significant economic impact and potential for rapid spread (Shafaati et al., 2024). Global strategies should focus on the development and distribution of genotype-matched vaccines, which are tailored to target the most prevalent NDV genotypes, thereby enhancing vaccine efficacy and control measures. Collaborative efforts among countries can facilitate the sharing of research, resources, and best practices to improve vaccine development and deployment.

8.2 National policies for NDV vaccine distribution and regulation

National policies play a crucial role in the distribution and regulation of NDV vaccines. Effective national strategies should include routine vaccination programs, as demonstrated by the increased flock size and reduced mortality in vaccinated chicken populations in Kenya (Otiang et al., 2021). Regulatory frameworks must ensure the availability of safe and effective vaccines, such as the recombinant vaccines that provide long-term protection with a single dose (Shi et al., 2024). Additionally, policies should support the use of innovative vaccination methods, such as spray vaccination, which are particularly suitable for large-scale poultry farms (Zeng et al., 2024).

8.3 Recommendations for expanding global vaccine access

To expand global vaccine access, it is essential to address logistical and economic barriers. Recommendations include the development of cost-effective vaccines that can be easily administered, such as the recombinant NDV vaccines that offer dual protection against multiple diseases (Tian et al., 2020). Increasing the availability of vaccines in developing countries, where ND poses a significant threat, is critical. This can be achieved through international aid and partnerships that focus on building local vaccine production capabilities and distribution

networks. Furthermore, enhancing public awareness and education about the benefits of vaccination can improve uptake and compliance among poultry farmers.

In summary, the successful eradication of Newcastle disease in chicken populations hinges on coordinated international efforts, robust national policies, and strategies to expand vaccine access globally. These measures will ensure the effective control and prevention of ND, safeguarding the poultry industry and supporting global food security.

9 Concluding Remarks

The case study on the eradication of Newcastle disease (ND) in chicken populations through vaccination highlights several key findings. The use of thermoresistant vaccines, such as ND.TR.IR, has shown high efficacy in providing protection against virulent NDV strains in various chicken types, including SPF, native, and broiler chickens, with protection rates reaching up to 100%. Additionally, recombinant vaccines like rHVT-005/006-F and rHVT-US2-F have demonstrated long-term protection with a single dose, offering a promising solution for sustained immunity. The study also found that routine vaccination programs significantly increased flock sizes in smallholder farms, indicating a positive impact on poultry productivity.

Vaccination plays a crucial role in the eradication of Newcastle disease by reducing virus transmission and mortality rates. The use of vector vaccines, such as the rHVT-ND, has been shown to significantly lower the reproduction ratio of the virus, thereby reducing the spread of the disease among vaccinated flocks. Moreover, comprehensive vaccination programs that include both live and inactivated vaccines have been found to provide higher protection rates and reduce viral shedding compared to live vaccines alone. These findings underscore the importance of vaccination as a primary strategy in controlling and potentially eradicating ND.

The future prospects for controlling and eradicating Newcastle disease globally are promising, given the advancements in vaccine development and administration strategies. The development of vaccines that provide long-term protection with fewer doses, such as the recombinant turkey herpesvirus-based vaccines, offers a practical approach to widespread immunization. Additionally, the integration of vaccination with other health management practices, such as parasiticidal treatments, can further enhance flock health and productivity. Continued research and adaptation of vaccination protocols to local conditions will be essential in achieving global eradication of Newcastle disease.

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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