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Genetic Diversity of Circulating Chicken Astroviruses and Their Economic Impact on Broiler Chickens

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Abstract

Chicken Astroviruses (CAstVs) are emerging pathogens that pose significant challenges to the poultry industry, resulting in substantial economic losses through diseases such as runting-stunting syndrome (RSS), White Chick Syndrome (WCS), and kidney disease. The high genetic variability of CAstVs complicates diagnostics and prevention efforts, creating significant hurdles in effective disease management. This review provides an in-depth analysis of the genetic diversity of CAstVs, their epidemiology, clinical impact, and associated economic implications, while also examining current diagnostic methods and strategies for disease control and prevention.

Introduction

Astroviruses are small, non-enveloped RNA viruses belonging to the Astroviridae family, characterized by their star-shaped morphology under electron microscopy. These viruses have been implicated in a range of enteric diseases in mammals and birds, with chicken astroviruses (CAstVs) being recognized as important contributors to economic losses in poultry production **(Saif *et al*., 2020- Swayne *et al*., 202).** CAstVs have been detected in both healthy and diseased chickens, indicating their ubiquitous presence across poultry farms and complicating control measures **(Snodgrass, 1979- Woode, 1985).** Several investigators have reported the abundance of astrovirus in the intestines of broiler chickens and its prevalence in commercial chickens and turkey flocks from the ages of 2 to 6 weeks **(Pantin-Jackwood, 2007- Shah, 2016).** CAstV usually infects chickens at an early age **(Shah, 2016- Smyth, 2017).** The fecal-oral route is the major transmission route **(Koci, 2002).** Reports have demonstrated that young chickens are mostly infected horizontally via contaminated housing due to an inadequate downtime period between flocks of either broilers or layers and a weak biosecurity that could lead to the introduction of the virus into the farm (**Smyth, 2017). ** Presently, three to four types of CAstV-related ill-

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nesses or conditions exist based on infectious virus strains **(Smyth, 2017):** RSS or uneven growth **(Baxendale, 2004- Bosch, 2012),** enteric and locomotion disorders **(DeWit, 2011),** kidney disease with visceral gout **(Bosch, 2012),** and white chick hatchery disease **(Sajewicz, 2016)** or white chick syndrome (WCS) **(Saif, 2020- Nuñez, 2020- Smyth, 2012).** Noteworthy, previously isolated Middle East CAstV strains were found to share more than 96% amino acid homology with Indian strains, suggesting the circulation of group B-CAstV in the Middle East. CAstV infection in Egypt represents a challenge facing poultry production by afecting the growth, feed conversion rate, and bird performance. Early detection and frequent screening of breeder focks are required to maintain the fock's health and to ensure the highest performance **(Ahmed A, 2023).**

The intensification of poultry farming, driven by the global demand for poultry meat and eggs, has increased the risk of widespread CAstV infections. The crowded conditions in commercial poultry operations facilitate the rapid transmission of these viruses, contributing to frequent outbreaks. This review aims to provide a comprehensive overview of the genetic diversity of CAstVs, their clinical manifestations, economic impact, and control strategies to mitigate their effect on broiler chickens.

Genetic Diversity of Chicken Astroviruses

1. Genomic Structure and Key Features

CAstVs are positive-sense, single-stranded RNA viruses approximately 7.5 kb in length. The genome is composed of three open reading frames (ORFs): ORF1a, ORF1b, and ORF2. ORF1a and ORF1b encode non-structural proteins, including a serine protease and RNA-dependent RNA polymerase (RdRp), whereas ORF2 encodes the capsid protein, which plays a crucial role in viral antigenicity and host immune response **(Bosch, 2012- Bosch, 2014).** The capsid protein, located on the outer surface of the virus, is responsible for receptor binding and immune evasion. The capsid protein is divided into distinct regions: a conserved N-terminal domain, a hypervariable region believed to form the capsid spike that interacts with host receptors, and a C-terminal domain involved in capsid stability. This high degree of genetic variability, particularly in the hypervariable region, allows the virus to evade host immune responses and adapt to different hosts **(Finkbeiner, 2008- Pantin-Jackwood, 2011).**

2. Genetic Diversity and Phylogeny

The high mutation rate of CAstVs, coupled with frequent recombination events, contributes to the significant genetic diversity observed among circulating strains. Phylogenetic analyses have identified two major genogroups, Group A and Group B, each further divided into multiple subgroups (Ai, Aii, Aiii for Group A, and Bi through Bvi for Group B) **(Smyth, 2013- Todd, 2009- Kwoka, 2021).** Group A strains tend to be associated with milder clinical presentations, while Group B strains are often linked to more severe disease manifestations **(Shah, 2016).** The diversity within these genogroups and subgroups poses significant challenges for disease control, as different strains may exhibit varying levels of virulence and immunogenicity. Moreover, different genogroups and subgroups can circulate simultaneously within the same flock, leading to mixed infections that complicate diagnosis and disease management **(Palomino-Tapia, 2020 - Yin, 2021)**.

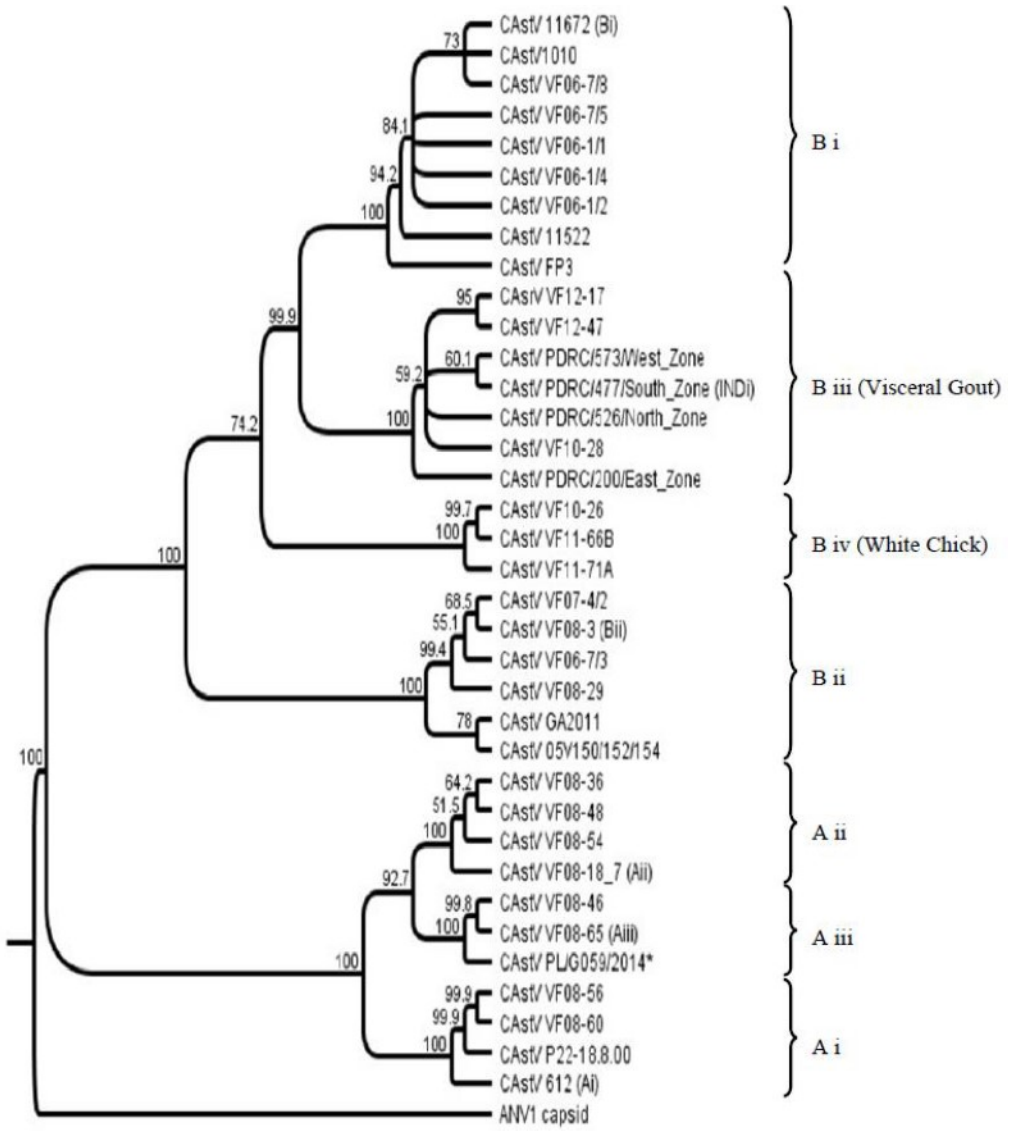

Figure (1). Chicken astrovirus (CAstV) open reading frame (ORF) 2 amino acid sequence. Phylogenetic tree of CAstVs based on complete ORF 2 (capsid) amino acid sequences. The tree was constructed using Geneious v6.1.8 (Biomatters, Auckland, New Zealand) using the neighbor-joining method and 1000 bootstrap replicates (bootstrap values are shown on the tree). Avian nephritis virus serotype 1 (ANV-1) was used to root the tree.

3. Recombination and Mutation

CAstVs are characterized by their high propensity for genetic recombination, particularly within the capsid gene (ORF2). The lack of proofreadaing capability in the viral RNA polymerase results in an elevated mutation rate, allowing the virus to rapidly adapt to new environments, evade host immunity, and potentially enhance its pathogenicity **(Palomino-Tapia, 2020 - Yin, 2021)**. Recombination between different CAstV strains, or between CAstVs and other avian astroviruses, has been identified as a key mechanism driving the evolution of these viruses. This genetic plasticity not only increases the diversity of circulating strains but also complicates vaccine development and makes it difficult to predict and control disease outbreaks **(Worobey, 1999)**.

Clinical Manifestations and Economic Impact

1. Disease Manifestations

CAstV infections in broilers can result in several clinical syndromes, each contributing to significant economic losses:

Runting-Stunting Syndrome (RSS): RSS is characterized by poor weight gain, malabsorption, and uneven flock performance. Affected birds display stunted growth, reduced feed efficiency, and increased susceptibility to secondary infections. The impact of RSS on feed conversion efficiency and overall productivity can be considerable, leading to increased production costs and lower profitability **(Bosch, 2014- Kang, 2012- Kang, 2018- McNeilly, 1994)**.

White Chick Syndrome (WCS): WCS is associated with reduced hatchability, high embryonic mortality, and weak chicks. Surviving chicks often have pale plumage, appear lethargic, and have increased early-life mortality rates. The condition can lead to severe economic losses, particularly in breeder operations, due to decreased hatchability and the need for additional care and intervention for affected chicks **(Bosch, 2012- Saif, 2020- Sajewicz-Krukowska, 2016- Swayne, 2020)**.

Kidney Disease and Visceral Gout: CAstVs have been linked to nephritis and visceral gout in young broilers, leading to high mortality rates, especially in severe outbreaks. Kidney damage results in impaired excretion of uric acid, leading to urate deposition in visceral organs (gout). This condition is often associated with significant flock mortality and substantial economic losses due to increased culling and veterinary costs **(Bosch, 2012)**.

2. Economic Losses

The economic impact of CAstV infections in the poultry industry is substantial and multifaceted, driven by the following factors:

Reduced Hatchability: Outbreaks of WCS can lead to significant reductions in hatchability, with some cases reporting losses as high as 68%. Decreased hatchability directly affects the productivity of breeder flocks, reducing the number of viable chicks and increasing production costs **(Raji, 2022)**.

Decreased Growth Performance: RSS leads to poor growth rates, lower feed conversion efficiency, and uneven growth across flocks, which results in higher feed costs and a reduced number of marketable birds. This ultimately impacts the overall profitability of broiler operations **(Rajendra Bulbule, 2014)**.

Increased Mortality Rates: Kidney disease and visceral gout increase mortality rates in affected flocks, necessitating additional veterinary interventions and contributing to increased production costs and decreased returns. The high mortality rates observed during severe outbreaks can lead to significant economic losses due to both direct mortality and the need for culling affected birds **(Raji, 2022).**

The persistence of CAstVs in the environment and their resistance to commonly used disinfectants further complicate control efforts. Once established, the virus can be challenging to eliminate from poultry farms, necessitating increased investment in biosecurity and sanitation measures **(Bulbule, 2013)**.

Diagnostic Challenges

Diagnosing CAstV infections is complicated by the genetic diversity of the virus and the frequent occurrence of co-infections with other enteric pathogens. Reverse transcription polymerase chain reaction (RT-PCR) assays targeting conserved regions of ORF1b are commonly used; however, sequencing of the ORF2 capsid gene is often required for precise strain identification **(Koci, 2002- Pantin-Jackwood, 2011)**. The presence of other enteric viruses, such as reoviruses, rotaviruses, and adenoviruses, further complicates the diagnostic process, making it difficult to determine the primary causative agent of clinical symptoms **(Finkbeiner, 2008)**.

Serological assays, such as enzyme-linked immunosorbent assays (ELISA), are also employed to detect antibodies against CAstVs; however, the high variability in capsid proteins can lead to cross-reactivity and reduced specificity. This variability necessitates the continual development of new diagnostic reagents to ensure accurate detection **(Kang, 2018)**.

Control Strategies and Prevention

1. Biosecurity Measures

Maintaining stringent biosecurity protocols is crucial for controlling the spread of CAstVs within and between poultry farms. Biosecurity measures include thorough sanitation of poultry houses, extended downtime between production cycles, and isolation of infected flocks to prevent transmission. The virus's stability in the environment and resistance to common disinfectants make it particularly difficult to eliminate, necessitating rigorous disinfection protocols and the use of effective antiviral agents **(Koci, 2002)**.

In addition to sanitation, controlling the movement of personnel, equipment, and vehicles between farms is essential to reduce the risk of CAstV introduction and spread. Implementing all-in/all-out production systems and reducing stocking densities can also help minimize the risk of infection **(Koci, 2002)**.

2. Vaccine Development

Developing effective vaccines against CAstVs is challenging due to the virus's high genetic variability and the frequent occurrence of recombination events. Current research efforts are focused on identifying conserved regions of the capsid protein that could serve as targets for vaccine development. The goal is to produce a vaccine capable of offering cross-protection against multiple strains of CAstV, thereby reducing the incidence and severity of infections **(Sellers, 2010).** Despite significant progress in understanding CAstV immunology, no commercial vaccines are currently available. As a result, poultry producers must rely on biosecurity measures, improved management practices, and careful monitoring to mitigate the impact of CAstVs. Future research should prioritize the identification of broadly protective antigens and the development of cost-effective vaccination strategies to provide long -term protection against CAstV infections **(Lee, 2013).**

Conclusion

Chicken astroviruses present significant challenges to the poultry industry due to their high genetic diversity, adaptability, and capacity for rapid evolution. The resulting complex disease dynamics lead to considerable economic losses, affecting hatchability, growth performance, and overall flock health. Effective management of CAstV infections requires a multifaceted approach, including improved surveillance, robust diagnostic tools, rigorous biosecurity measures, and investment in vaccine development targeting conserved viral regions. Continued research into the mechanisms of mutation and recombination in CAstVs will be crucial for informing future disease control strategies, ultimately minimizing the economic burden of CAstV infections on poultry production.

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