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AVIAN HEALTH UNDER THREAT: TRENDS IN POULTRY DISEASES AND THEIR IMPACT ON GLOBAL PRODUCTION

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Abstract

Poultry production as part of the global poultry industry is important in ensuring food security because it provides a major source of protein to human populations worldwide. Yet it is being increasingly threatened by a variety of new infectious diseases, which have serious consequences for both animal health and poultry production sustainability. In this review, the major infectious diseases in poultry are considered according to prevalence, economic consequences and global distribution, with a focus on viral, bacterial, parasitic and fungal causes of infection. Furthermore, the paper addresses the increasing threat of fast-evolving, emerging and reemerging poultry diseases caused by climate change, globalization, pathogen mutation, and biosecurity lags. As an important way, the prevention and control of the disease, such as vaccination programs and improvement of biosecurity and surveillance systems, must be stressed to reduce risk to the poultry industry. The paper also focuses on the economic cost of poultry diseases, including the costs of reduced productivity, treatment, culling and trade restrictions. The zoonotic potential of poultry diseases and antimicrobial resistance potential of feed additives make this a case of public health importance, and there is a need to manage these diseases in a manner that takes into account the impact on animal and human health. Additionally, global and regional frameworks, roles of international organizations (WHO, OIE, FAO), national poultry health programs and regulations on trade are reviewed. In conclusion, the paper suggests that plans for further innovation of vaccines, diagnostics, and surveillance should proceed, along with the practice of sustainable farming and a One Health approach to poultry health and food security for the present and future. Particular attention is given to the necessity of joint actions of different governments, industries, and research institutions in resolving the multifactorial problems connected with poultry diseases.

Keywords: Avian health, Food security, Global poultry production, Poultry diseases, Poultry industry

INTRODUCTION

BACKGROUND ON THE GLOBAL POULTRY INDUSTRY AND ITS IMPORTANCE IN FOOD SECURITY

Poultry production has been the fastest growing segment of the livestock industry provided an important source of global food security, livelihoods and economic development. Global poultry meat production stands at around 137 million tonnes at the time of writing, while global egg production has surpassed 93 million tonnes, and both continued to rise over the past decade (1). One of the most accessible sources of high-quality animal protein is poultry, especially chicken, and its ultimate importance in fighting protein-energy malnutrition in particular developing countries (2).

There are shorter generation intervals and few religious constraints, and moreover feed conversion efficiency in poultry that makes this enterprise one of the preferred enterprises in both rural and urban areas (3). Millions of families in many low and middle income countries rely on smallholder poultry farming as source of income and food. However, in high income countries, industrial-scale poultry production is the dominant form of raising poultry to feed large populations and generates significant amounts of export earnings (1). For instance, in the total global broiler production, the United States, Brazil, and China all sum to more than 50% (4).

RATIONALE FOR FOCUSING ON POULTRY HEALTH

However, as a result of these advantages, poultry health remains a major bottleneck to sustainable production. Disease outbreaks will significantly knock down productivity, quality of meat and eggs, as well as profitability, resulting in over USD 10 billion annually in global economic losses (5). Avian Influenza (AI), New castle Disease (ND), and Mycoplasmosis are persistent major threats in places with an absent veterinary infrastructure, high bird densities, and low biosecurity, as is the case in many parts of the World (6).

In addition, the intensified and globalized production of poultry renders it more susceptible to newly arising and re-occurring infectious diseases. For instance, in the past five years, several waves of outbreaks caused by the H5N1 and H5N8 strains of Avian Influenza in Europe, Asia and Africa, have led to mass culling and trade disruptions (7). Moreover, growing global crisis of antimicrobial resistance (AMR) in cattle and poultry use have seen a misuse and overuse of antibiotics in animal farming, which undermines animal health and presents risks to human health through zoonotic transmission and vice versa (8).

Backyard poultry systems and live bird markets are hotspots for diseases transmission and present risks to poultry, humans, and other animals in LMICs where the regulatory oversight is weak (9). Moreover, international trade, climate change and wildlife interaction further add complications to the poultry sector's disease dynamics, making it necessary to adopt One Health approach for managing avian disease (10).

OBJECTIVES AND SCOPE OF THE REVIEW

This review therefore sets out to present an up to date and comprehensive review of the most serious disease threats to global poultry health and their direct and indirect effect on production systems. Specifically, the review seeks to:

- Study the major viral, bacterial, parasitic, and fungal poultry diseases throughout the world.
- Identify trends for emerging and re-emerging diseases, including animal to human threats (zoonotic diseases).
- Calculate the economic burden and trade implications of disease outbreak events.
- Evaluate existing strategies of controlling, preventing, and surveillance within different production systems.
- Localize policy, research, and technological gaps and make recommendations for sustainable disease management.

This review is intended to support policy makers, researchers, and industry stakeholders in designing more resilient, health conscious poultry systems that not only lead to food security but also to a healthy public.

OVERVIEW OF POULTRY PRODUCTION SYSTEMS

TYPES OF POULTRY PRODUCTION

Poultry production represents a highly diverse class of systems in terms of management practices, productivity, and vulnerability to disease. There are four basic types of production, which are broiler farming, layer production, backyard poultry, and industrial operations (Table I).

BROILER PRODUCTION

When raised for meat, the broilers are slaughtered after reaching slaughter weight (2–3 kg) within 35–45 days under good circumstances. To expand, broiler production has been driven by genetic selection, nutrition and environment control to reach feed conversion ratio (FCR) as low as 1.6 in a commercial operation (11). U.S., Brazil, and China are leading producers of broiler products, with the broiler industry being mostly concentrated in the high income and emerging economies. Broiler meat is becoming increasingly popular with consumers across the world because of its affordability, shorter production cycle and its lower carbon footprint over ruminant meat (12).

LAYER PRODUCTION

Hens that are layers are hens bred for maximum egg output. Commercial modern layers can produce an average of 320–350 eggs per hen per year, peaking between 25 and 40 weeks of age. There are systems of different degrees of welfare such as cage based, cage free, free range where the pressure for increasing welfare friendly systems in EU and USA is more and more. Eggs have been regarded as an affordable nutrition source in regions of Asia where dietary protein demands are growing and in an expanding global egg industry (13).

Raising backyard poultry is usual in rural households in Africa and South Asia. These (usually native) birds are kept in small flocks of 5 – 20, permitted to scavenge for their feed and receive limited veterinary care. While productivity is low approximately 80–100 eggs per year per hen, these systems have very important food security, dietary diversity, and income roles, especially in the livelihoods of low income families and women (14). Still, inadequate housing, little biosecurity, and few vaccines mean birds are prone to a wide variety of infectious diseases.

INDUSTRIAL/COMMERCIAL PRODUCTION

In high income countries and recently in emerging markets these are the large scale, vertically integrated, systems. Thousands of birds are kept in climate-controlled sheds run by industrial farms with central control of feed, the provision of veterinary services, and the processing of birds. Although so efficient, such systems are vulnerable to disease amplification caused by crowding, genetic uniformity, and stress. In these high-density setups health challenges including avian influenza, necrotic enteritis and antimicrobial resistance are a particularly concerning issue (15).

Table I. Types of poultry

Type of poultry	Description	Key Features
Broilers	Chickens raised specifically for meat production.	Rapid growth, short production cycle, high feed efficiency.
Layers	Chickens raised for egg production.	Long production cycle, continuous egg-laying, high feed conversion.
Backyard poultry	Small-scale poultry farming, often integrated with family households.	Low-input systems, mixed breeds, limited biosecurity.
Industrial poultry	Large-scale commercial farming focused on mass production of eggs or meat.	High-density housing, mechanized systems, strict biosecurity protocols.

GEOGRAPHIC DISTRIBUTION AND ECONOMIC SIGNIFICANCE

One of the most prevalent types of animal farms is poultry farms which have been practiced across continents. Because of its low capital requirement especially in smallholder systems, rapid turnover, and increasing demand for animal source foods it has become a key part of food systems.

Asia is the world's largest producer of both poultry meat and eggs, and China and India are among the top five producers. In 2023, China alone produced over 34 million metric tons of poultry meat (16).

The largest producer of broilers in North America, and in the world, is the United States, which processes around 9 billion broilers annually and is also an important exporter of broilers to many of the world's major importing regions. Not only does Brazil represent a key global supplier of poultry meat, export of such commodities to over 150 countries, especially in the Middle East and Asia, is suggested. Rapid expansion of poultry systems can be seen in Africa and South Asia due to their urbanization as well as their income levels. But infrastructure and a paucity of veterinary services are still issues.

The poultry sector also creates employment, opportunities for trade and enhances the GDP. The industry is valued at over USD 420 billion on a global level and is expected to grow further on account of booming demand for low-cost animal protein and high per capita consumption in developing economies (17). Additionally, backyard poultry is managed by women in low-income households and therefore poultry farming supports gender inclusive livelihoods (Table II).

Table II. Geographic distribution and economic significance of poultry

Region	Poultry production (Broilers/Layers)	Economic significance
North America	Pre dominantly industrial broiler production.	Major contributor to food security and employment; large export market.
Europe	Strong presence of both broilers and layers.	Economic pillar for many countries; highly regulated industry for animal welfare.
Asia-Pacific	Significant growth in industrial poultry; also large backyard sector.	Rapidly growing sector; key for domestic consumption and export, especially in countries like China and India.
Africa	Pre dominantly backyard poultry with increasing industrial production in some areas.	Vital for local food security; emerging industrial sector as urbanization rises.
Latin America	Both broilers and layers, with large industrial farms in countries like Brazil.	Export leader (especially Brazil), key sector for employment and GDP.

INTENSIVE VS. EXTENSIVE FARMING AND HEALTH IMPLICATIONS

Disease emergence and transmission is largely driven by the mode of poultry production. The disease dynamics are determined by the type of system, intensive or extensive (high input, high output or low input, low output), which describes systems by story lines.

INTENSIVE SYSTEMS

As intensive they are characterized by controlled environment, formulated feeds and strict production systems. Predictable output, high feed efficiency, and better opportunity for disease surveillance are some of the benefits. However, challenges include:

- Stressing the work with high stocking densities, which also enhances the risk of pathogen spreading.
- More use of antibiotics and vaccines, which fosters antimicrobial resistance.
- Stress-induced immunosuppression (birds are more likely to become infected with respiratory or enteric infections).
- Loss of pathogens including *E. coli*, *Salmonella*, or *Clostridium perfringens* which, once established in a flock, are difficult to eradicate (18).

EXTENSIVE SYSTEMS

In the rural and peri-urban areas, extensive or semi intensive systems are common. An ability to forage more freely allows birds to develop immune systems better. However:

- The disease may be introduced into domestic settings by the infection of wild birds, rodents and contaminated environment and by exposure to avian influenza and Newcastle disease.
- Underreporting and an inadequate disease control are caused by inadequate vaccination coverage, the lack of diagnostics, and trade that is not formalized.
- Moreover, smallholder poultry farming in highland area can be limited by low productivity, high mortality (up to 40% in some traditional systems), and low level of poultry product commercialization, which may render it economically unviable for smallholder producers (19).

Interventions for health must be brought into the realm of the socio economic and environmental realities of that system. Intensive systems may, perhaps, be aided by technological innovation, while extensive systems need investment in basic veterinary infrastructure, education, and access to cheap vaccines.

Table III. Intensive vs. Extensive Farming Systems and Health Implications

Farming system	Characteristics	Health implications
Intensive Farming	High-density, controlled environments, mechanized production, and high feed input.	Increased risk of disease outbreaks (e.g., avian influenza, <i>Salmonella</i>); high use of antibiotics.
Extensive Farming	Low-density, free-range or backyard systems, organic or minimal inputs.	Lower disease risk due to natural behaviors and lower stress; however, limited veterinary access can lead to under-diagnosis.

MAJOR INFECTIOUS DISEASES IN POULTRY

Infectious diseases continue to be one of the most serious threats to poultry health and production and trade. Lastly, these diseases result in grave loss of economic resources because of low productivity, high rate of mortality and the costs of disease control. They cluster by virus, bacteria, parasite and fungal/mycotoxin illnesses.

VIRAL DISEASES

Some of these diseases are viral, which are some of the most damaging to poultry in that they can spread rapidly across flocks causing acute and chronic illness. Avian Influenza (AI), Newcastle Disease (ND), Infectious Bronchitis Virus (IBV), and Marek's Disease are the most important viral diseases in poultry (Table IV).

AVIAN INFLUENZA (AI)

Bird flu is a highly contagious virus of the influenza A family, specifically H5N1 and H7N9 subtypes, that can affect and infect both domestic and wild birds. Infection in poultry can lead to sudden death, respiratory and swelling. It can also mutate to highly pathogenic forms that cause severe disease outbreaks as well as devastating effects for the poultry industry. Therefore, the rapid transmission among birds, and the fact that the virus itself can affect humans, have raised huge global public health and economic concerns (20). Strict biosecurity measures and culling infected flocks are all part of how to control outbreaks.

NEWCASTLE DISEASE (ND)

The cause of the Newcastle Disease is the avian paramyxovirus type 1 (APMV-1) and it specifically affects both wild and domesticated poultry. ND is very contagious and is characterized by a variety of clinical signs ranging from mild signs of the respiratory and gastrointestinal tracts to sudden death. Outbreaks can result in the massive losses incurred through system culling, regulatory trade restrictions, and significant economic losses. The disease is very dangerous because it can be transmitted very quickly by aerosolized droplets. In many places, vaccination is the primary preventative strategy, but not always enough to prevent the spread of more virulent strains (21).

INFECTIOUS BRONCHITIS VIRUS (IBV)

Infectious Bronchitis is a highly contagious viral disease affecting the respiratory system of poultry and characterized by being caused by the Infectious Bronchitis Virus (IBV). Besides producing respiratory symptoms, IBV can also cause kidney damage and egg production loss. Commercial layer farms are especially plagued by the disease, because it can quickly result in a huge drop in egg quality and quantity. Being highly variable, with many different serotypes in circulation, it is very difficult to develop a universal vaccine (22). Strictures of biosecurity are essential for rapid spread via contaminated equipment, water or air.

MAREK'S DISEASE

Marek's Disease is induced by herpesvirus, infecting chickens and describes tumors, immunosuppression and neurological disorders. Unvaccinated birds can die from the disease which causes mortality rates up to 100%. Intensive farming systems where chickens are housed in large numbers are especially a problem for Marek's disease. Vaccination of chicks represents the most effective control means, and most commercial poultry are vaccinated at young age to reduce the incidence of the disease (23).

Table IV. Viral diseases in poultry

Diseases	Causative agent	Transmission route	Symptoms	Economic impact
Avian Influenza (AI)	Influenza A virus	Direct contact, droppings, airborne	Respiratory distress, reduced egg production, sudden death in severe cases	Major disruptions in trade; culling costs; impact on global poultry industry
Newcastle Disease (ND)	Newcastle disease virus	Direct contact, aerosols	Respiratory signs, nervous signs, drop in	Trade restrictions, culling, productivity losses



Infectious Bronchitis Virus (IBV)	(NDV) Coronavirus	Aerosols, direct contact, contaminated feed and water	egg production Coughing, nasal discharge, reduced egg quality	Economic losses due to decreased egg quality and hatchability
Marek's Disease	Herpesvirus (MDV)	Aerosol, feather follicles, contact with contaminated equipment	Paralysis, skin tumors, immune suppression	Vaccine costs, significant loss in broiler production

BACTERIAL DISEASES

Infections of poultry caused by bacteria result in a number of diseases among which mentioned are Salmonellosis, Colibacillosis (*E. coli* infection), Fowl Cholera, and Mycoplasmosis. Although these diseases are often considered secondary, they complicate poultry management and are associated with poor hygiene, inappropriate management practices of poultry farms, and the indiscriminate use of antibiotics (Table V).

SALMONELLOSIS

Of bacterial diseases affecting poultry, those caused by *Salmonella enterica* serotypes are among the best known. *Salmonella* can be carried by the poultry without the birds showing symptoms, however multiplication and clinical illness can occur in the stressed birds. The symptoms of the disease, which include diarrhea, lethargy and dehydration, can lead to major mortality in especially severe cases. *Salmonella* is a major food safety risk, too, as it can transmit to humans through contaminated eggs and meat, as well as being a problem for the welfare of poultry overall. Measures of control are through vaccination, good sanitation and good monitoring (24).

COLIBACILLOSIS (*E. COLI* INFECTION)

Another common form of bacterial disease in poultry is the *Escherichia coli* (*E. coli*) infection, which are caused by pathogenic strains of the bacterium. Egg peritonitis, respiratory symptoms and septicemia are common end products of these infections. *E. coli* associated diseases are frequently triggered by environmental stressors for example overcrowding, poor sanitation and sudden changes in diet; secondly, *E. coli* is present as secondary pathogens complicating other diseases; and thirdly becoming potential source of economic loss through mortalities as well as treatment costs (25).

FOWL CHOLERA

The bacterium that causes fowl cholera is *Pasteurella multocida* and results in the acute systemic disease which may include the clinical features of head and neck swelling, respiratory distress and sudden death. Fowl cholera is a major concern in poultry farming, both for the large scale commercial operations and the backyard farms. The disease is spread by direct contact with infected birds or diseased water and feed. Control of outbreaks in commercial farms (26) depends on vaccination and proper management practice.

MYCOPLASMOSIS

Bacteria of the genus *Mycoplasma*, which causes mycoplasmosis, can affect the respiratory, reproductive and gastrointestinal systems of poultry. *Mycoplasma gallisepticum* and *Mycoplasma synoviae* are the most common species causing chickens to be infected. The symptoms associated with the infection are coughing, nasal discharge and swollen joints. The disease is chronic and as a result, can reduce productivity, and low growth rates. The lack of available effective antibiotics makes mycoplasmosis difficult to treat (27), and vaccination is the most effective measure for prevention.

Table V. Bacterial diseases in poultry

Disease	Causative agent	Transmission route	Symptoms	Economic impact
Salmonellosis	<i>Salmonella</i> spp.	Oral ingestion, contaminated feed or water, direct contact	Diarrhea, fever, septicemia, abortion in layers	Impact on public health, export bans, culling
Colibacillosis (<i>E. coli</i>)	<i>Escherichia coli</i>	Direct contact, contaminated	Respiratory distress, peritonitis,	Antibiotic treatments,



		water/feed	septicemia	decrease d growth rate
Fowl Cholera	<i>Pasteurella multocida</i>	Direct contact, contaminated water/feed	Sudden death, depression, respiratory distress	Culling, antibiotic treatments, productivity loss
Mycoplasmosis	<i>Mycoplasma gallisepticum, Mycoplasma synoviae</i>	Aerosol, fomites, vertical transmission	Respiratory signs, joint swelling, reduced growth rate	Long-term effects on egg production, veterinary costs

PARASITIC DISEASES

Poultry can be very parasitic especially in free range and backyard systems. Coccidiosis and infestation by ectoparasites and helminths are key parasitic diseases (Table VI).

COCCIDIOSIS

Eimeria is a protozoan parasite causing the disease coccidiosis. It is mainly in the intestines, causing diarrhea, dehydration and slows a growth rate. Coccidiosis is especially devastating in broiler systems in which large numbers of birds are kept in close confinement. The disease has potential to cause noticeable economic losses in treatment and reduced feed conversion efficiency. Anticoccidial drugs and vaccination programs are typically used for management of coccidiosis (28).

ECTOPARASITES AND HELMINTHS

Poultry disease can be caused by ectoparasites such as mites, lice, and fleas that entice irritation, feather loss, and anemia. In many cases, these parasites carry other diseases and can seriously compromise the welfare of poultry in free range systems. Poultry can be parasitized by internal parasitic infections, most notably helminths (worms) which can affect poultry digestion and absorption of nutrients leading to poor growth and poor immune system. For these parasites, regular treatment and good hygiene and biosecurity with these parasites are required.

Table VI. Parasitic diseases in poultry

Disease	Causative agent	Transmission route	Symptoms	Economic impact
Coccidiosis	<i>Eimeria</i> spp.	Fecal-oral route	Diarrhea, weight loss, poor growth rate, bloody stools	Treatment costs, decreased growth and feed conversion
Ectoparasites and helminths	Various species (e.g., <i>Dermanyssus gallinae</i> , <i>Ascaridia galli</i>)	Direct contact, ingestion of eggs or larvae	Feather damage, anemia, weight loss, diarrhea	Reduced productivity, costs of treatment (e.g., dewormers, pesticides)

FUNGAL AND MYCOTOXIN-RELATED ILLNESSES

Molds produce fungal infections and mycotoxins, secondary metabolites, which are important pathogens to poultry health. Mainly, it involves diseases such as Aspergillosis and Aflatoxicosis (Table VII).

ASPERGILLOSIS

Aspergillosis is the disease caused by the fungus *Aspergillus* which affects mainly respiratory system of poultry. Fungal infections of the lungs and air sacs occur in birds from inhaling spores from contaminated bedding or feed. Symptoms may include wheezing, lethargy and out of sorts feed intake in infected birds. Confined poultry systems with poor ventilation and humidity control, as such, are more prone to aspergillosis (29).

AFLATOXICOSIS

Aflatoxicosis is due to the ingestion of aflatoxins, toxic compounds produced by molds like *Aspergillus flavus*. Feed grains become contaminated by these toxins causing liver damage, immune suppression and growth retardation of poultry. Exposure of poultry to aflatoxins over an extended period of time can result in significant loss of animals and have been known to lead to death. Food safety issues to humans through consumption of contaminated eggs and meat with aflatoxin are a critical issue in the regions where contaminated grains are fed to poultry are (30).

Table VII. Fungal and mycotoxin-related illnesses in poultry

Disease	Causative agent	Transmission route	Symptoms	Economic impact
Aspergillosis	<i>Aspergillus</i> spp.	Airborne spores	Respiratory distress, decreased growth, death in severe cases	Treatment costs, reduced growth rates, veterinary care
Aflatoxicosis	<i>Aspergillus flavus</i> (mycotoxin-producing fungi)	Ingestion of contaminated feed	Poor growth, immune suppression, liver damage, reduced egg production	Losses in egg and meat production, feed contamination concerns

EMERGING AND RE-EMERGING DISEASES

Emerging and reemerging diseases have alarmingly increased in the poultry industry and pose a threat to global poultry health and food security. These diseases are of considerable animal welfare, public health, and economic risks. All of the diseases that have leveled up to the status of emerging or reemerging diseases are newly identified or previously unrecognized infections that affect poultry populations (Table VIII) (31).

DEFINITION AND CAUSES OF EMERGING POULTRY DISEASES

New poultry diseases are usually dynamic changes of interactions among hosts and pathogens, with newly emergent pathogens or more virulent, resistant or adaptive pathogens. They may develop from spillover from wild birds or other animal reservoirs, adaptation of the pathogen to new hosts, as a result of human activity including international trade, deforestation, or others. On the other hand, reemerging diseases like fowl cholera and New castle disease, come back into the picture due to a break in vaccination, weak disease surveillance, or evolution of the microbe (32). Changing conditions have allowed pathogens such as *Clostridium perfringens*, *Mycoplasma synoviae* and highly pathogenic avian influenza strain such as (H5N8) and (H7N9) to emerge or reemerge with a capacity for causing disease (33).

KEY DRIVERS OF EMERGING AND RE-EMERGING DISEASES

Temperature, humidity, and precipitation patterns change and affect the ecology of disease vectors, as well as survival of pathogens in the environment. Warmer, wetter conditions could lead to an increased proliferation of parasites such as coccidia; increase the survival of bacteria in litter; or increase the spread of viruses via migrating birds. Birds can also be stressed by extreme weather events, owing to immunosuppression, whereby they are more likely to be infected (34).

The rapid transport of poultry products, live birds, and materials for feeding poultry around the world promotes the rapid dissemination of infectious agents across borders. Although legal and illegal international trade, worsens the risk of introduction of exotic pathogens in naïve poultry populations (35). Since commercial poultry farming expands into new regions with low or no biosecurity infrastructure in place, disease spread may be further exacerbated.

Many viruses, such as avian influenza virus and infectious bronchitis virus, mutate constantly, giving rise to newly emerged types of subtypes that have distinct pathogenicity and antigenicity. These mutations can make control programs more problematic, since such mutations render existing vaccines useless. Antibiotic resistant strains are on the rise as these antibiotics are causing death of non-resistant species leading to horizontal gene transfer among bacteria (36).

One of the main risk factors for disease emergence and re-emergence is still inadequate biosecurity. Small backyard and small scale producers of poultry, especially in low income areas do not have adequate housing, vaccination protocol or sanitation protocol. Outbreaks can occur even in large commercial farms, if there is a lapse in biosecurity (e.g. reuse of contaminated equipment, poor disposal of dead birds) (31).

Table VIII. Emerging and re-emerging diseases in poultry

Aspect	Description
Definition	Emerging diseases are newly identified or rapidly increasing in frequency or geographic distribution. Re-emerging diseases are diseases that had previously been under control but have made a resurgence.

Causes of emerging diseases	<ul style="list-style-type: none"> - Zoonotic Spillover: Pathogens transferred from wildlife or other animals to poultry. - Pathogen Mutation: Genetic changes in viruses or bacteria leading to increased virulence or resistance. - Biosecurity Gaps: Inadequate biosecurity practices leading to pathogen introduction.
Drivers of emerging and re-emerging diseases	<ul style="list-style-type: none"> - Climate Change: Alters the distribution and activity of vectors (e.g., mosquitoes) and affects pathogen survival. - Globalization and Trade: International movement of poultry and poultry products increases the risk of pathogen introduction. - Pathogen Mutation: Genetic shifts or reassortment in viruses and bacteria can make them more transmissible or virulent. - Poor Biosecurity: Inadequate management practices (e.g., lack of hygiene, unregulated movement of animals) facilitate pathogen spread.
Case studies/examples	<ul style="list-style-type: none"> - Avian Influenza (AI): Emerged and re-emerged in multiple regions, with new strains (e.g., H5N1, H7N9) causing economic disruption and public health concerns (e.g., Asia, Africa). - Newcastle Disease (ND): Re-emerged due to lapses in vaccination and biosecurity in some regions (e.g., Africa, Middle East). - Coccidiosis: Emerging resistance to treatment in broilers due to overuse of coccidiostats, causing increased morbidity and mortality in some areas.

REGIONAL CASE STUDIES AND EXAMPLES

Recurring outbreaks of highly pathogenic avian influenza (HPAI), namely H5N1 and H7N9 strains, have occurred in Southeast Asia. Massive poultry losses and trade disruption, and concerns about zoonotic transmission have resulted from these viruses. Live bird markets in China and Vietnam have been called major transmission hubs for the virus and have been shut down periodically and monitored closely as a result (37).

Newcastle disease is endemic in most African countries and is highly ranked as the most economically important poultry disease on the continent. Limited vaccine access coupled with poor cold chain infrastructure and the prevalence of free range poultry system are associated with recurrent outbreaks, and are responsible for the spread of diseases (32).

During the last couple of years, Europe has observed the increase of *Mycoplasma synoviae* infections, especially in layer flocks. Previous to this, strains were thought of as a secondary pathogen, but with emerging strains there are now associations with synovitis and eggshell apex abnormalities leading to production losses (35).

A number of variants of infectious bursal disease virus (IBDV) have reappeared in Latin America with increased virulence and induction of immunosuppression in young birds and predisposition of those birds to other infections. Backyard, and commercial, scale operations have been affected by these outbreaks (33).

Broiler breeders and layers were affected by re-emergence of fowl cholera, caused by *Pasteurella multocida*, in some parts of the Middle East. The re-emergence is accredited, in most cases, to biosecurity lapses, environmental stressful factors and inappropriate vaccination (36).

ZOONOTIC POTENTIAL AND PUBLIC HEALTH CONCERNS

Zoonotic disease transmission continues between poultry and humans through the same interface (poultry), as a threat to public health. A number of poultry associated pathogens can directly or indirectly transmit to humans and cause foodborne outbreak, respiratory disease and antibiotic resistant infection. In regions with poor biosecurity and little disease surveillance, it is critical to understand these threats and the types of interventions that would be appropriate (Table IX).

TRANSMISSION OF POULTRY DISEASE TO HUMAN

Many of the poultry associated pathogens are pathogens of humans. Contact with infected birds in markets or during home slaughter (38) usually causes human infections with severe respiratory illness by avian influenza viruses (e.g H5N1 and H7N9). Furthermore, *Salmonella*, *Campylobacter*, and some *E. coli*

strains are responsible for a significant amount of food borne disease burden at the global level which are spread through meat, eggs, or unhealthy food handling (39).

A second route of transmission is occupational exposure. Poultry workers processing and handling poultry are often at increased risk of zoonotic infection through direct contact with feathers, fecal material, or aerosols (40).

Table IX. Major zoonotic pathogens associated with poultry and their human health effects

Pathogen	Disease in humans	Transmission route	Severity	
Avian (H5N1)	Influenza	Severe respiratory illness, pneumonia	Contact with infected birds/aerosols	High
<i>Salmonella enterica</i>	Gastroenteritis, septicemia	Contaminated meat/eggs		Moderate
<i>Campylobacter jejuni</i>	Diarrhea, Guillain-Barré syndrome	Undercooked poultry, cross-contamination		Moderate
<i>E. coli</i> (ESBL strains)	Urinary tract infections, septicemia	Direct/indirect contact, foodborne		Variable

Source: Adapted from WHO (2023); ECDC (2022); Sims & Harder (2022)

ANTIMICROBIAL RESISTANCE (AMR) CONCERNS

The global AMR crisis is also being fueled by poultry farming. However, the development and spread of resistant bacteria have resulted from widespread use of antibiotics in feed, water, and as prophylactics. Isolation of multidrug resistant strains of *Salmonella*, *Campylobacter*, and *E. coli* has been isolated in poultry meat and eggs which is a direct source of risk to the consumers (41, 42).

Not only are these resistant organisms difficult to treat in humans, but they also make horizontal resistance gene transfer possible to other bacteria, which may negate the efficacy of human antibiotics. The threat of AMR must be approached from a 'One Health' standpoint, meaning it involves all three: animal health, human health and the environment (Table X).

Table X. Common antimicrobial-resistant bacteria isolated from poultry

Bacterial species	Common resistance traits	Public health risk level
<i>Escherichia coli</i>	β -lactams (ESBL), tetracycline	High
<i>Salmonella enterica</i>	Fluoroquinolones, ampicillin	High
<i>Staphylococcus aureus</i>	Methicillin (MRSA)	Moderate to High
<i>Campylobacter jejuni</i>	Macrolides, fluoroquinolones	High

Source: Van et al. (2021); Sharma et al. (2023)

BIOSECURITY GAPS IN LIVE BIRD MARKETS AND BACKYARD FARMS

However, in terms of control of the transmission of zoonotic disease, live bird markets (LBMs) and backyard poultry systems identify as weak links. These systems, however, do not have sanitation protocols, do not monitor for diseases, and do not take appropriate controlled use of antibiotics. Different poultry species are able to mix in LBMs, therefore overcrowded and poorly ventilated, allowing the evolution and pitfall of pathogens (43).

The problem with backyard farms, particularly as they lack veterinary oversight, is that they tend to be particularly susceptible to undetected outbreaks. Birds often roam freely and mingle with wildlife, and any cross species transmission is possible. The biosecurity gaps make it very likely for emergent zoonoses with pandemic potential to rise (44).

ECONOMIC IMPACT OF POULTRY DISEASES

Globally, poultry diseases constitute a major burden to the commercial and small scale poultry industries. These effects manifest themselves in reductions in productivity, rising healthcare costs, and great disturbances to trade. Outbreaks of diseases can spread down supply chains, erode consumer confidence and undermine national food security (Table XI).

LOSS IN PRODUCTIVITY

The causes of disease (like Newcastle disease and the avian influenza) together along with infectious bronchitis lead to reduced feed efficiency, weight gain, and egg production. Often, the effects of the illness result in stunted growth, higher mortality and poor carcass quality of the affected birds, resulting in immediate economic losses to the producers. For example, coccidiosis has been estimated to cost the global

poultry industry over US \$3 billion a year in impaired growth and feed conversion (45). For example, in laying hens, infectious bronchitis, as well as Mycoplasma, infections cause a tremendous decrease in egg quality and quantity; resulting in lower revenues for the producers. On the other hand, even subclinical infections in which the symptoms are not apparent can lead to measurable productivity reduction (46).

Prevention and control of diseases incur a high cost that includes veterinary care, vaccination programs, diagnostic testing and biosecurity infrastructure. Multivalent vaccines and antibiotics (where allowed) are often given in conjunction with intensive operations and can amount to as much as 1 – 2% of production costs (47).

On top of that, disease not controlled adequately may end up in emergency culling or mass treatment further driving costs. In extremely poor areas where the veterinary infrastructure is not very developed, the use of informal treatments and the misuse of drugs lead to persistence of the disease and development of resistance, which can make these interventions even costlier in the long run.

Outbreaks of highly pathogenic avian influenza (HPAI) often close access to markets and therefore lead to halting poultry exports trade from affected regions. They can last up to months and can lead to billions in lost revenue. For example, the 2021–2022 HPAI outbreaks in Europe and Asia led to the culling of over 50 million birds and poultry trade being disrupted in over 20 countries (48).

Control measures that are commonly practiced, such as culling the infected and exposed birds, are highly damaging financially to farmers, with delays and insufficiency of compensation worsening the situation by a huge margin. In addition, the downstream industries include feed production, processing, and transport are affected negatively.

CASE STUDIES OF OUTBREAKS AND THEIR ECONOMIC FALLOUT

CASE STUDY 1: AVIAN INFLUENZA IN THE UNITED STATES (2015 & 2022)

For example, the 2015 disease outbreak devastated the U.S., resulting in culling of over 50 million birds and losses of US \$3.3 billion. In 2022 there was a resurgence of avian influenza resulting in the loss of an additional 40 million birds and a price increase in egg and poultry meat across the board (49).

CASE STUDY 2: NEWCASTLE DISEASE IN SUB-SAHARAN AFRICA

Endemic Newcastle disease has been reported to cause the annual losses in excess of US \$100 million through high mortality and reduced productivity in backyard and smallholder systems in Nigeria and neighboring countries (50).

Table XI. Estimated economic impact of major poultry diseases

Disease	Type	Estimated Global annual losses	Key affected areas
Avian Influenza (HPAI)	Viral	> US \$10 billion (outbreak-related)	USA, EU, Asia
Coccidiosis	Parasitic	~ US \$3 billion	Global
Newcastle Disease	Viral	> US \$100 million (Nigeria)	Sub-Saharan Africa
Infectious Bronchitis	Viral	> US \$500 million	Asia, South America
Mycoplasmosis	Bacterial	Unknown, but significant	Developing poultry economies

Source: Adapted from FAO (2022); Khan et al. (2023); Dibia et al. (2021); Shirley et al. (2021); USDA (2022)

DISEASE CONTROL AND PREVENTION STRATEGIES

The control and prevention of poultry diseases is important for the health of the animals, the profitability of the farm and the health of the public as well as the security of world food supply. Managing endemic and emerging poultry pathogens requires an integrated approach of combining vaccination, strict biosecurity, active disease surveillance, and training of the farmers (Table XII).

VACCINATION PROGRAMS

However, vaccination as a cornerstone of preventing disease in poultry still remains. Viral diseases include Newcastle disease, infectious bronchitis, Marek's disease and avian influenza, which are controlled by regular and especially targeted immunization programs. Since vaccines are pathogen, production systems, and location dependent, and need to be stored, handled and administered according to schedules (51).

Advances in recombinant and vector vaccines have led to improved efficacy and safety of immunization programmes in the large scale commercial operations. Vaccination coverage is suboptimal in backyard and smallholder systems, as vaccination is a cost, access and technical knowledge limited practice (52).

BIOSECURITY AND HYGIENE PRACTICES

Biosecurity is a suite of practices to prevent the introduction and spread infectious agents in and between poultry farms. Key biosecurity measures include:

- Controlled access to poultry houses
- Disinfection of equipment and vehicles
- All-in/all-out production systems
- Quarantine of new birds
- Rodent and wild bird control

Good bio security also means that outbreaks are greatly reduced if not eliminated. Nevertheless, gaps in practice, particularly in low-income countries, still deprive disease prevention. Farms that are strictly following biosecurity protocols, report lower disease incidence and antibiotic use (53).

SURVEILLANCE AND EARLY DETECTION SYSTEMS

Detecting early outbreaks and being able to respond and contain them is possible, thanks to surveillance systems. But effective disease monitoring is only possible when laboratories are regularly sampling, diagnosing and reporting on individuals who fall ill. Meanwhile, global disease tracking and data sharing in global frameworks, including OIE-WAHIS and FAO's EMPRES-i, is also done (1). With more and more local government adopting digital technologies such as mobile apps and GIS platforms, reporting and traceability for disease is enhanced. Still, underreporting, insufficient lab capacity or delayed diagnosis poses huge challenges especially in other parts of the world (54).

FARMER EDUCATION AND TRAINING

To combat disease is essential the farmer awareness of diseases and capacity building. Training farmers on vaccination protocols, hygiene management, and early detection of diseases strengthens farmers to preemptively resort to measures and reduce antibiotics dependency.

Promising results in increasing knowledge and practices in poultry management have so far been found through farmer field schools, extension services, and mobile based learning platforms. Furthermore, group vaccinations as well as the joint investment in biosecurity infrastructure can be managed by farmer cooperatives (55).

Table XII. Key poultry disease control strategies and their benefits

Strategy	Description	Benefits
Vaccination Programs	Targeted immunization against common pathogens	Reduced morbidity, mortality, and economic loss
Biosecurity Practices	Physical and procedural barriers	Prevention of disease introduction and spread
Surveillance Systems	Monitoring and early outbreak detection	Rapid response and reduced transmission
Farmer Education	Training on best practices	Improved compliance and reduced antibiotic misuse

Source: Adapted from Ghaniyeh et al. (2022); FAO (2023); Yilma et al. (2023)

GLOBAL AND REGIONAL RESPONSE FRAMEWORKS

Control of poultry diseases requires global as well as regional efforts. The leading role in surveillance, policy development and building capacity is assigned to multilateral organizations such as the World Health Organization (WHO), World Organisation for Animal Health (WOAH, previously OIE) and Food and Agriculture Organization (FAO). In addition, disease risk management efforts are complemented at the national level and through regulating the trade of animals and animal products, providing food systems and animal health security.

WHO, OIE, AND FAO INITIATIVES

Collaboration with veterinary organisations and governments working on poultry related zoonotic threats is the responsibility of the World Health Organization (WHO). It is One Health initiative encourages the response to human, animal and environmental health in an integrated way. This has proven to be very important in the management of avian influenza and antimicrobial resistance (56).

Global disease surveillance and reporting is coordinated by the WAHIS platform of the World Organisation for Animal Health (WOAH). WOAH is the setting of international trading standards for which animal health, trade and disease notification occurs improving early warning and rapid response systems (57). Food and Agriculture Organization (FAO) plays a big role too and under the helm of the FAO, global programs such as EMPRES (Emergency Prevention System), are in place to increase preparedness for transboundary animal diseases. Finally, EMPRES aids countries to improve laboratory competence, upscale veterinary services, and increase biosecurity (48).

Many of these agencies cooperate on large projects, for example on the Global Framework for the Progressive Control of Transboundary Animal Diseases (GF – TADs) for important zoonoses, including avian influenza and New castle Disease.

NATIONAL POULTRY HEALTH PROGRAMS

Several countries have developed national poultry health strategy and activities, for instance in disease surveillance, vaccination campaign, farmer training, and emergency preparedness. For example:

- This disease such as Salmonella and avian influenza are being managed in United States by the implementation of its National Poultry Improvement Plan (NPIP) through the certification, monitoring, and biosecurity standards (49).
- The National Action Plan for Egg and Poultry – Vision 2022 in India is aimed to improve productivity, health services and market access (58).
- A Nigerian project called the Avian Influenza Control and Human Pandemic Preparedness Project (AICP) was launched with a goal of strengthening public-private coordination in outbreaks response (59).

Nevertheless, these programs have been constrained by barriers in the low and middle income countries including, underfunded veterinary services, poor infrastructure, and lack of potential stake-holder coordination.

ROLE OF INTERNATIONAL TRADE REGULATIONS

The Sanitary and Phytosanitary (SPS) Agreement of the World Trade Organization (WTO) requires International trade in poultry and poultry products to be regulated such that the sanitary or phytosanitary measures should be the result of a risk assessment which is science-based and not maintained without sufficient scientific evidence. Reference guidelines in global poultry trade assessments are provided by the WOAH.

Trade bans or restrictions are common with these disease outbreaks, and especially with outbreak of highly pathogenic avian influenza (HPAI). All of these actions carry huge economic implication to exporting countries and underscore the importance of transparent disease reporting and following international health protocols (60).

In some cases, global public goods, such as plant and animal health, are regulated substantively across borders by regional bodies (European Union (EU), the African Union (AU), etc.) including movement control, traceability systems and harmonized surveillance.

FUTURE DIRECTIONS AND RESEARCH NEEDS

As the poultry industry confronts evolving challenges in animal health, environmental sustainability, and public health, future progress hinges on innovations in science, technology, and policy. Emerging tools such as advanced diagnostics, genomic research, and data-driven systems hold promise for

transforming poultry disease control, while interdisciplinary frameworks like One Health are essential to managing zoonotic risks. This section highlights key areas for future research and innovation.

DEVELOPMENT OF NOVEL VACCINES AND DIAGNOSTICS

The emergence of new poultry pathogens and the persistence of highly mutable viruses like avian influenza underscores the need for next-generation vaccines. Current research is focused on recombinant vaccines, vector-based delivery systems, and thermostable formulations suitable for rural settings. These technologies aim to enhance immunity, reduce cold-chain dependency, and offer broader protection against variant strains (61).

Equally important are innovations in rapid diagnostics, including point-of-care molecular tests and biosensors that can detect multiple pathogens simultaneously. The integration of CRISPR-based diagnostics and lab-on-a-chip devices promises earlier detection and targeted interventions in both commercial and backyard flocks (62).

GENOMIC TOOLS FOR DISEASE RESISTANCE

Advances in genomics and bioinformatics are enabling selective breeding for disease-resistant poultry strains. Whole-genome sequencing and gene-editing tools such as CRISPR-Cas9 are being used to identify and manipulate genes associated with immune response, growth, and productivity (63). These genomic strategies may reduce the industry's reliance on antimicrobials and vaccines by enhancing innate resilience.

Research also continues into host–pathogen interactions, microbiome modulation, and epigenetic regulation, opening new pathways for personalized nutrition and immune enhancement in poultry farming.

SUSTAINABLE FARMING AND ONE HEALTH INTEGRATION

Sustainable poultry production must align with the One Health concept, which promotes integrated management of animal, human, and environmental health. Future systems must address antimicrobial resistance (AMR), waste management, and carbon emissions while ensuring animal welfare and economic viability.

Promising strategies include integrated multi-trophic farming, use of organic and herbal feed additives, and closed-loop systems to recycle poultry litter into biogas or fertilizer. Holistic farm management practices are being piloted in various regions to demonstrate the dual benefits of productivity and environmental stewardship (64).

Cross-sectoral research is also needed to quantify the cost-effectiveness of One Health interventions and assess their scalability in low- and middle-income countries.

USE OF AI, BIG DATA, AND PRECISION LIVESTOCK FARMING

The digital transformation of poultry farming is gaining momentum with the adoption of artificial intelligence (AI), machine learning (ML), and Internet of Things (IoT) technologies. Precision livestock farming enables real-time monitoring of animal health, behavior, feed intake, and environmental conditions. These systems support early disease detection, optimize resource use, and reduce human error. For instance, AI-powered cameras and acoustic sensors can identify coughing, lameness, or unusual movements indicative of disease onset (65).

Big data analytics are also being used to track epidemiological trends and forecast outbreaks, while blockchain technologies promise improved traceability and biosecurity compliance across poultry value chains.

CONCLUSION

The global poultry industry is facing unprecedented challenges due to the rising incidence and complexity of infectious diseases, many of which are exacerbated by intensifying production systems, climate change, and increased global trade. This review has highlighted the major viral, bacterial, parasitic, and fungal diseases affecting poultry, along with their profound implications for animal welfare, food security, public health, and economic sustainability. Particularly concerning is the zoonotic potential of

several pathogens and the growing threat of antimicrobial resistance, which reinforces the need for vigilant disease monitoring and cross-sectoral coordination.

Emerging and re-emerging poultry diseases are evolving in response to ecological, genetic, and anthropogenic pressures. As shown by recent outbreaks in diverse regions, such threats demand rapid innovation and adaptability in control measures. The review also emphasized that existing gaps in biosecurity—especially in live bird markets and backyard systems—remain a weak link in global disease containment efforts.

Moving forward, a more integrated and sustainable approach to poultry health is essential. This includes the development of novel vaccines and diagnostics, leveraging genomic and digital technologies, and adopting One Health frameworks that holistically address the interconnectedness of human, animal, and environmental health. Furthermore, precision livestock farming and AI-based surveillance tools hold great promise in transforming disease detection and response mechanisms.

This review calls on governments to invest in stronger veterinary infrastructures and surveillance systems, industry stakeholders to adopt bio-secure and welfare-friendly production practices, and researchers to pioneer context-specific solutions that balance productivity with sustainability. Only through collaborative, interdisciplinary efforts can the poultry sector overcome current threats and ensure a healthier, more resilient future.

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