Review Article

Zoonoses in the Indian Poultry Sector and Prospect of One Health Approach as a Sustainable Solution- A Review

ABSTRACT

The Indian poultry sector has witnessed noticeable amplification in recent years. Still, it has also been plagued by the emergence of zoonotic diseases, posing significant threats to public health, food security, and the economy. This abstract explores the alarming rise of zoonotic diseases in the Indian poultry industry and highlights the urgent need for a One Health approach to address emerging challenges. The One Health framework, which emphasizes the interconnectedness between human, animal, and environmental health, holds promise as a sustainable solution to mitigate zoonotic epidemics in the poultry sector. This study reviews the challenges, potential benefits, and key considerations associated with implementing the One Health approach in India, emphasizing its role in preventing and controlling zoonotic outbreaks in poultry birds, improving bird welfare, and fostering sustainable operation in the poultry industry thereby securing human and environmental health and well-being. It underscores the importance of collaboration among various stakeholders, including government agencies, veterinary and medical professionals, and the poultry industry, to promote a holistic and resilient approach to zoonoses management.

Keywords: Zoonoses, One Health, Poultry, Sustainable Development

1. INTRODUCTION

The twenty-first century is the age of globalization and urbanization, characterized by more and more free flows of people, animals, and goods worldwide. Therefore, the concept of One Health has gained importance like never before. The primary assumption behind this idea is that the environment and human and animal health are intimately connected and interdependent. Any naturally transmissible infection from vertebrate animals to humans is called zoonosis. Zoonotic diseases associated with poultry are becoming an increasing threat to public health due to different reasons. For instance, projections indicate a continual rise in the global human population, nearing 10 billion by 2050 [1]. This trajectory inevitably entails a surge in food demand. Consequently, there is anticipation for an increase in poultry and other livestock populations to meet this demand, especially considering the significant nutritional contribution of dairy and meat products. However, the Food and Agriculture Organization (FAO) forecasts that it is necessary to have over 70% more animal protein to sustain the growing population by 2050 [2]. Such expansion heightens the risk of zoonotic pathogen transmission to humans. The OIE suggests that 61% of pathogens that cause human diseases originate from domestic animals or wildlife. Another fact is that 75% of emerging human pathogens are of animal origin.

Avian zoonoses in India have a rich and intricate history, with a legacy of diseases transferring from birds to humans spanning centuries. These zoonotic infections have provoked considerable apprehension due to their potential to spark widespread outbreaks and pose substantial public health threats [3]. The most common zoonotic disease in India is Avian influenza, caused by viral infection, primarily affecting birds. Highly Pathogenic Avian Influenza (HPAI) threatens both animal and human health and continues to spread [4]. The HPAI H5N1 virus was initially detected in domestic geese in 1996 [5]. The first HPAI (H5N1) outbreak in India was recorded in February 2006 in Maharashtra and Gujarat, followed by another in March 2006 in Madhya Pradesh. This resulted in the cruel culling of 7.2 million birds, with West Bengal and the Murshidabad district experiencing the most dangerous outbreaks. The outbreaks occurred in chicken farms, wild bird species, and backyard poultry, with a higher frequency during the winter due to favorable survival conditions for the virus. Various avian influenza subtypes, including H5N1, H9N2, H4N6, H11N1, H4N2, H9N3, H2N2, and H3N2, have been identified in several bird species and ducks in India [6]. While human infections by avian influenza viruses are rare, specific subtypes, such as A(H5N1) and A(H7N9), have caused significant illnesses in humans. Other subtypes, including H7N3, H7N7, and H9N2, have also infected humans [7]. From 2003 to January 20, 2016, the World Health Organization reported 846 laboratory-confirmed human cases of avian influenza (H5N1) virus in 16 countries, resulting in 449 fatalities [8]. Despite these avian influenza cases in poultry birds in India, no human cases have been reported. The economic impact on India's poultry sector has been substantial. The Asian Development Bank estimated that avian influenza could cost the country between 1.8 and 5.8 percentage points of GDP. Reports of avian influenza have come from various states in India, with confirmation from ICAR-NIHSAD at 12 epicenters. Notably, the zoonotic potential of bird influenza became evident with the tragic death of an 11-year-old child from Haryana in 2021 at Delhi's All India Institute of Medical Sciences, marking the nation's first such fatality [9]. The H5N1 and H5N8 strains have been identified in India since January 2021. Multiple bird deaths were reported in Himachal Pradesh's Pong Lake and Maharashtra among peacocks, near Gujarat's Kharo Dam in Junagadh, and among forest crows in Uttarakhand. As of February 12, 2021, 449,271 poultry birds were culled following the confirmation of avian flu outbreaks.

Therefore, this review aims to describe the most significant zoonotic diseases concerning poultry sectors. Based on etiology, zoonoses in poultry are classified into bacterial zoonoses, viral zoonoses, fungal zoonoses, and protozoan zoonoses. Table 1 lists the major zoonotic diseases in poultry with their etiological agents and significant symptoms [10]. It is important to note that decent knowledge of these diseases and their transmission is crucial since it enables people to act, including introducing proper risk assessment models. It involves the application of new technologies such as metagenomics, which is now the primary method used to identify novel viruses. From a global point of view, the critical reference regarding risk assessment models is the tripartite guide addressing zoonotic diseases, which experts developed from the FAO, WHO, and OIE. Besides, constant epidemiological surveillance and report systems must be timely and efficient since surveillance in animals and humans is critical for the early identification and possible prediction of future outbreaks, allowing for preemptive action. Similarly, timely, accurate, and reliable laboratory tests are critical for identifying etiologies of disease and monitoring both endemic and emerging zoonotic diseases in humans and livestock, which allows for implementing proper prevention, detection, and response strategies. However, it is essential to note that animals other than livestock can also be a risk for human health, including, e.g., dogs and cats (rabies) and wildlife (rabies, tularemia, and Lyme disease). Another critical perspective regards climate change and the possible detrimental influence on vector-borne diseases, which may, in the future, expand and alter the geographical ranges of biological vectors and, consequently, their zoonotic diseases.

Table 1: Major Zoonotic Diseases, their etiological agents, and the primary symptoms

Zoonotic Disease	Etiology	Major Symptoms
Viral Zoonotic Diseases		
Avian Influenza (Bird Flu)	Influenza A virus	Swollen heads, Blue combs and wattles, Dullness, Lack of appetite, Respiratory distress, Diarrhea, Purple discoloration,
Newcastle Disease Virus	Paramyxovirus,	Loss of appetite, Coughing, Gasping, Nasal discharge, Watery eyes, Bright green diarrhea, Paralysis and convulsions,
West Nile Virus	West Nile virus	Abnormal head posture, Wobbly gait, Inability to stand, Staggering, Tremors
Japanese Encephalitis	Japanese Encephalitis Virus	lack of appetite, staggering, and paralysis
St. Louis Encephalitis	St. Louis Encephalitis Virus	Encephalitis, Depression, Excitement, Lack of appetite, Staggering, Paralysis, Blindness, Difficulty holding their head
Bacterial Zoonotic Diseases		
Salmonellosis	*Salmonella enterica*	Weakness, Loss of appetite, Watery diarrhea, crowding close to heat sources, Sitting with drooping wings and closed eyes
Campylobacteriosis	*Campylobacter jejuni*	Spotty liver disease, Diarrhea, Vomiting
Chlamydiosis (Psittacosis)	*Chlamydia psittaci*	Poor appetite, Ruffled appearance, Eye or nose discharge Green or yellow-green droppings, Diarrhea, Breathing difficulty
Avian Tuberculosis (M. A. complex)	*Mycobacterium avium*	Weight loss, White diarrhea, Dull and ruffled feathers, Increased thirst, Lethargy, Depression, Pale comb, wattles, and earlobes
Yersiniosis	*Yersinia pseudotuberculosis*	Ruffled feathers, Debilitation, High mortality, Persistent diarrhea, Weakness, Lameness, Progressive emaciation
Erysipeloid	*Erysipelothrix rhusiopathiae*	General weakness, Depression, Diarrhea, Sudden death, Cutaneous lesions, Swollen hocks,
Fowl Cholera/ Pasteurellosis	*Pasteurella multocida*	Inflammation of the conjunctiva and sinuses, swelling and darkening of the face and wattles, loss of appetite, weight loss
Fungal Zoonotic Diseases		
Aspergillosis	*Aspergillus fumigatus*	Difficulty breathing, Coughing, Silent gasping, Lethargy, Fluffed, Listless, Weight loss, Thirst, Drowsiness, Nervous signs
Candidiasis	*Candida albicans*	Listlessness, Inappetence, Dejection, Poor appetite, Diarrhoea, Thick, large white patches on the inside of chicken's mouth
Protozoan zoonotic diseases		
Cryptosporidiosis	*Cryptosporidium* sp.	Diarrhea, Dehydration, Coughing, Gasping, Airsacculitis, Death, Poor appetite, Weight loss
Toxoplasmosis	*Toxoplasma gondii*	Weight loss, Loss of appetite, Shrunken comb, whitish diarrhea, Trembling, Torticollis (twisting of the neck), Blindness

ZOONOTIC DISEASE TRANSMISSION IN THE POULTRY BIRDS: INDIAN PERSPECTIVES

Poultry birds could play a critical role in transmitting zoonotic diseases, thus raising concerns due to the potentially severe public health consequences of many of these diseases [11]. Identifying and separating sick birds from those displaying symptoms was an essential initial step to prevent disease transmission. It would be necessary only to allow people or anything near the flock once consulting a veterinarian after handling a diseased bird or its environment [12]. Disease transmission can happen through different modes, primarily by close contact with sick birds, inhalation, ingestion, etc. Contamination occurs through mucous membranes, damaged skin, body fluids, secretions, and excretions. Unprotected contact with tissues during postmortem examination was often reported to carry a high risk of transmission [13]. Aerosols were occasionally involved, particularly in confined spaces. Fomites could transmit some agents; the likelihood of this route correlated with the organism's persistence in the environment [14]. Some microorganisms were transmitted by ingesting contaminated food or water and might infect humans. Sources of zoonotic pathogens in humans were found to take the route of foodborne disease mainly via undercooked meat [15]. Once infected, the person could act as a source of spreading the zoonotic disease in the community. The risk varied according to the specific agent, its ability to spread in humans, and the transmission routes. Often, the most at-risk humans were healthcare workers and close family members. Certain zoonotic diseases may not initially be contagious, but they can become transmissible under favorable conditions or through blood transfusions or organ transplants, potentially impacting others [16, 17]. The agents, potentially managed effectively within the organ donor, could become active again in the recipient, who undergoes immunosuppression via medication to thwart rejection [18].

CHALLENGES IN THE INDIAN POULTRY SECTOR: ESPECIALLY EMPHASIZING BIRD HEALTH AND WELL-BEING FROM ZOONOSES ANGLE

Recently, there has been notable growth in the Indian poultry industry, establishing itself as a vital contributor to the country's economic prosperity. Despite achieving significant milestones, this sector faced several challenges threatening its long-term sustainability and effectiveness. Overcoming these obstacles and ensuring sustainability in the poultry sector required a collaborative approach that involved various stakeholders [19]. The Indian poultry industry grappled with various challenges, such as disease outbreaks, non-clinical use of antibiotics, environmental pollution, inadequate education, and limited surveillance [20]. Rampant use of antibiotics for treating illnesses, injuries, and stress-related symptoms posed a significant concern [21]. This practice raised alarms about the emergence of antibiotic-resistant bacteria and disruptions in gut microbiota, as noted by Manyi-Loh et al. [22] and Yadav and Jha [23]. Widespread use of antibiotics not only impacted poultry health but also emerged as a risk to human health and the environment. Transmission of antibiotic-resistant bacteria and soil and water contamination were documented issues [24], fostering the development of antibiotic resistance in environmental bacteria that could potentially spread to other organisms [25]. India faced significant hurdles to ensure sustainability in the poultry sector that necessitated addressing, including the imperative for enhanced education and technological access [26]. Another critical concern was identified as limited genetic diversity in poultry breeds. This concentration raised the risk of widespread diseases nationwide. Nonetheless, the exotic breeds demonstrated adaptability to Indian conditions [27]. Even today, poultry dressing facilities are predominantly operated manually, and more sanitary measures are needed. Such deficiency jeopardized the prospects of achieving a hygienic and scientifically sound slaughtering process [28]. Additionally, a shortage of skilled personnel, including managers, veterinarians, nutritionists, and researchers, acted as a final obstacle, demanding top-notch management for each operation.

ONE HEALTH APPROACH: A SUSTAINABLE SOLUTION ENSURING THE COLLECTIVE WELL-BEING OF THE ANIMALS, PEOPLE, AND THE PLANET

The One Health approach represents a comprehensive and cooperative strategy acknowledging the interdependence of animal, human, and environmental health. The significance of this concept is particularly evident in managing zoonotic diseases, which could transfer between animals and humans, including those impacting poultry. The One Health approach aims to proactively address, identify, and respond to zoonotic diseases by recognizing the interconnections and interdependency of animal, human, and environmental well-being [29]. One Health underscores the close correlation between human health, animal health, and our shared environment. Although not a new concept, its importance has surged in recent years due to changes in interactions among people, animals, plants, and the environment [30]. Adopting One Health is increasingly recognized in the United States of America and globally as an effective means to combat health challenges at the interface of animal, human, and environmental factors, particularly zoonotic diseases [31]. The Centers for Disease Control and Prevention (CDC) employed a One Health approach by engaging animal, human, and environmental health experts and other pertinent disciplines and sectors to monitor and control public health threats. This collaboration involved doctors, nurses, public health practitioners, epidemiologists, veterinarians, paraprofessionals, agricultural workers, ecologists, wildlife specialists, law enforcement, policymakers, and members of communities and pet owners [32]. The One Health approach emphasizes fostering communication and coordination among these diverse stakeholders. Doing so could achieve optimal health outcomes for animals, humans, and plants within a shared environment. The One Health strategy's potential benefits included preventing zoonotic diseases, improving food safety and security, mitigating antimicrobial resistance, safeguarding global health security, and supporting biodiversity and conservation efforts [33]. In combating zoonoses in the poultry sector, interdisciplinary collaboration is crucial. This collaboration brings together experts from various fields, including veterinarians, microbiologists, epidemiologists, environmental scientists, and public health professionals [34]. Together, they address complex issues related to zoonotic diseases in poultry. Veterinarians play a crucial role in identifying animal health concerns, microbiologists study disease agents, and epidemiologists track the spread of diseases [35].

Interdisciplinary teams are pivotal in detecting and monitoring zoonotic threats through surveillance systems and data analysis [36]. Environmental scientists assess farming practices' role in disease transmission, aiding in developing guidelines for improved biosecurity and waste management. Public health professionals contribute to preventing zoonotic diseases from escalating into human health crises through awareness campaigns and control measures. Policymakers benefit from comprehensive data and recommendations, optimizing resources and preventing duplication of efforts [37]. Collaboration enhances education and training, fostering knowledge sharing and empowering stakeholders to take proactive measures. Cross-disciplinary teams drive research, leading to innovative tools and strategies for preventing and controlling zoonoses in poultry. This collaborative approach promotes a safer, more resilient poultry operation, safeguarding animal and human health wellness. Pivotal steps involved in the One Health Concept implementation included the following:

Monitoring and Early Preparedness: The importance of monitoring and early preparedness cannot be overstated in an ever-changing world, where pandemics and emergencies can strike at any moment [38]. Early detection and community alarm raising are pivotal in minimizing the impact of unforeseen events, enhancing community resilience, and saving lives [39].

- ***Early Detection:*** It is a crucial aspect of successful poultry farming in maintaining the

health and productivity of flocks [40]. Farmers employ various strategies to identify signs of illness or distress in poultry at the earliest stages. Regular health monitoring, including visual inspections and behavioral observations, allows farmers to spot any abnormalities in the birds' appearance, activity levels, or feeding behavior [41]. Additionally, implementing advanced technologies such as automated sensor systems and data analytics can provide real-time insights into the flock's health status [42]. Early detection enables prompt intervention and helps prevent diseases from spreading within the flock. Proactive measures in poultry farming contribute to improved overall welfare and sustainable farming practices [43].

- ***Community Alarm Raising:*** Community alarm raising is a collective effort of community members to address and respond to potential threats or challenges in the poultry industry. This proactive approach emphasizes the importance of fostering a sense of unity and shared responsibility among poultry farmers and neighboring residents [44]. Community members work together to raise awareness and take swift action during disease outbreaks, adverse weather conditions, or other poultry health emergencies. This includes disseminating information about preventive measures, organizing workshops on biosecurity practices, and establishing communication channels to alert each other quickly about any signs of trouble [45]. By promoting a culture of mutual support and vigilance, community alarm raising not only safeguards the well-being of the poultry birds but also strengthens the resilience of the entire poultry farming community, ensuring sustainable practices [46].

A well-prepared community exhibits greater resilience in adversity, facilitating a smoother recovery after a disaster. Moreover, early preparedness could save the lives of millions of poultry birds and humans and alleviate the financial burden on governments and communities that would otherwise grapple with the aftermath of a disaster. Monitoring and preparedness through early detection and community alarm-raising in disaster management are indispensable [47]. Collaborative efforts of technological advancements, government agencies, and engaged communities are the key to minimizing the impact of disasters and ensuring a safer, more resilient world [48].

Rapid Response: Implementing Standard Operating Procedures (SOPs): It is crucial to implement Standard Operating Procedures (SOPs) in poultry farms to prevent and address the risk of zoonotic diseases, which could transfer from animals to humans in the proximity of these settings. To establish effective SOPs and mitigate zoonotic hazards, begin with a comprehensive risk assessment that evaluates farm practices, animal health, and biosecurity measures [49]. Ensuring thorough training for farm personnel on zoonotic disease risks, symptoms, and prevention strategies, with regular updates on best practices; enforcing stringent biosecurity protocols including restricted access, controlled visitor entry, and rigorous cleaning coupled with mandatory use of personal protective equipment (PPE) for all farm workers when handling birds or farm-waste could effectively limit disease transmission [50]. Implementing a robust animal health management program with regular veterinary checks, vaccination, and quarantine procedures for new animals and setting guidelines for proper poultry waste disposal to prevent environmental contamination is essential. Establishing a continuous animal health monitoring system with a disease-reporting mechanism to promptly report potential issues is essential in managing zoonoses. Developing SOPs for specific zoonotic diseases relevant to the region and farm type, outlining containment measures, and reporting procedures were necessary [51]. Creating quarantine areas for sick birds and isolation protocols for humans and animals showing symptoms could be an effective barrier. Maintaining detailed records of animal health, vaccinations, and disease incidents could be

essential for traceability. Developing an emergency response plan for a zoonotic disease outbreak, including communication with authorities, could be an effective tool [52]. Conducting regular SOP audits, ensuring alignment with the latest research and recommendations, continuously evaluating and enhancing biosecurity measures at the farm level, and informing farm workers about the importance of following SOPs and maintaining good personal hygiene could play a vital role in disease management [53]. Further, establishing collaboration with local veterinary services, public health agencies, and stakeholders to share information and resources and engage in community outreach to educate neighbors and consumers about zoonotic disease risks and mitigation efforts were pointed out by Asaaga et al. [54].

Treatment Facilities for Birds and Humans: It is vital to build adequate treatment facilities and protocols to prevent and manage outbreaks and the potential threat of zoonotic diseases. Various government bodies in India address these disease management and provide treatment options for birds and humans through dedicated channels. Veterinarians and veterinary clinics could play a crucial role in the diagnosis and treatment of poultry-related zoonotic diseases, as well as in recommending preventive measures. State and national veterinary departments could often have specialized facilities and experts to manage outbreaks among birds [55]. India has avian health centers and laboratories that diagnose and treat poultry diseases, including zoonoses. These centers provide essential testing, surveillance, and guidance for outbreak control. Collaboration with local public health institutions, such as government hospitals and healthcare centers, could be crucial for zoonotic diseases affecting humans on poultry farms [51]. These institutions could offer medical treatment and guidance to the farmers, farm workers, and other individuals exposed to diseases from the infected birds. Government agencies might implement guidelines to manage zoonotic outbreaks, coordinate responses, and establish treatment facilities. Educational institutions, research centers, and universities could contribute by conducting research and providing diagnostic and treatment facilities, often in collaboration with government agencies. Non-governmental organizations and International Health organizations specializing in animal and public health could also play a vital role during zoonotic outbreaks. They could help set up treatment facilities, raise awareness, and assist with disease control and prevention. The key to dealing with zoonoses in Indian poultry farms lies in the prevention of the disease spread. Strict biosecurity measures, regular health monitoring, vaccination, and hygiene practices could significantly reduce the risk of outbreaks [19]. Early detection and reporting are critical, emphasizing the importance of coordination among relevant agencies and stakeholders to effectively respond to zoonotic diseases affecting birds and humans in the poultry industry [36].

Policy and Regulatory Framework: India has taken significant strides in enhancing its policies and regulatory structures within the poultry sector to combat zoonotic diseases—ailments [56]. Recognizing the imperative of keeping pace with potential advancements is pivotal. A robust One Health policy for India's poultry industry, focusing on zoonoses, encompasses several key elements [57]. A comprehensive approach to controlling zoonotic diseases necessitates collaboration among the veterinary, public health, and environmental sectors. Engaging with global organizations for knowledge exchange and support is highly recommended. Establishing a swift response plan coordinating with local, state, and national authorities is crucial to managing disease outbreaks efficiently. Encouraging poultry research and development investments, particularly in identifying and advancing new disease control technologies, is advisable. Infrastructure development and enhancing diagnostic laboratories and healthcare facilities are pivotal to this strategy. It is important to note that effectively implementing such a One Health policy and regulatory framework hinges on collaboration among diverse stakeholders—government agencies, representatives from the poultry industry, healthcare experts, and researchers. Additionally, the framework should exhibit adaptability and flexibility to address emerging challenges and scientific findings. For the most

recent updates on India's policies and regulations on the poultry sector and zoonoses, referring to official government sources and recent communications from relevant authorities is recommended. India's union and state governments offer Polyclinics, Veterinary Hospitals, Dispensaries, and Mobile Veterinary Dispensaries to reduce illness and death rates among poultry birds. The MoHFW India has sanctioned the Central Drugs Laboratory (CDL) to conduct quality assessments of veterinary biologicals related to Hemorrhagic septicemia and Ranikhet sickness. Regional Disease Diagnostic Laboratories provide referral services, contributing significantly to a holistic approach to managing bird welfare. The department is critical in addressing bird health concerns through the Livestock Health & Disease Control (LH&DC) Scheme, which offers financial support for preventive immunization, skill enhancement, disease monitoring, and fortifying veterinary infrastructure in order to ensure poultry birds' health safety. A solid commitment to readiness, control, and containment is evident in responses to avian flu outbreaks, employing measures like the Avian Influenza (AI) Action Plan and BirdFlu. ASCAD (Avian Sector Control and Containment Division) supports states and union territories in managing avian flu outbreaks in India. The Action Plan encompasses a surveillance strategy and ongoing enhancements through laboratory upgrades and personnel training to ensure preparedness [57]. Specialized BSL-III Laboratories, including a transportable BSL-III lab, have been established to diagnose Avian Influenza. The government prioritizes transparency in reporting epidemics and disseminates information through Information, Education, and Communication (IEC) initiatives. Regular advisories are issued to state governments, and countries with confirmed cases of Highly Pathogenic Avian Influenza are restricted from importing poultry or chicken products, underscoring the commitment to preventing the spread of avian influenza.

Sustainable management of poultry birds' health: Sustainability manifests in economic and ecological forms. Economic sustainability primarily concerns production and consumption, while ecological sustainability prioritizes the well-being of people and biodiversity [58]. It encapsulates the notion of 'development programs that meet human needs without jeopardizing the long-term capacity of natural resources, environmental quality, and social equity' [59]. A study by Khan [60] advised the introduction of selective breeding in desi breeds and crossbreeding with exotic or local kinds. Well-balanced feeding improves young chicks' health and metabolism. According to Rajkumar et al., [61] research revealed the cruciality of biosecurity and immunization for poultry health. They also advocated for mass vaccination initiatives with the support of local NGO teams, veterinary professionals, and government agencies to manage viral illnesses in poultry birds. Properly using a thermostable vaccination reduced Newcastle disease in backyard poultry birds [62]. Six-month deworming intervals were also advised, and deworming drugs were applied a week before vaccinating chickens to avoid viral infections [63]. Experts were found to recommend disinfecting poultry breeding and rearing settings highly. Small-scale up to intensive poultry farming required regular monitoring, training, reporting, and documenting breeding history, bird abnormalities, immunization, mortality patterns, etc. [64].

Multi-scale institutional environment for zoonoses management*:* India's health policy, regulatory operations, and disease and outbreak control are overseen by the MoH&FW. Healthcare and employee training are state-run. This picture shows that the NCDC, ICMR, and ICAR (indicated with an asterisk for research and innovation) work together in managing and preventing zoonoses. Variation in health (livestock and human) administration and capabilities at the state level impacts health policy decision-making and results. The federal government's position and availability of finances allow it to define and control state health agendas. This positively and negatively affected disease control [65]. The central government's involvement facilitated state buy-in for common disease monitoring programs like the Integrated Disease Surveillance Programme (IDSP). It boosted state-level efforts to manage disease outbreaks via money and technical recommendations [66]. National-level

agencies (usually perceived as an extension of central government authority) have significant dispositional capabilities in the hierarchical health system, which might reduce local health assistance.

ONE HEALTH APPROACH IN THE POULTRY SECTOR: INDIAN SCENARIO

Globally, One Health (OH) is gaining recognition for combating zoonotic diseases and achieving the UN's Sustainable Development Goals [67, 68]. It offers an integrated approach across human, animal, and environmental interfaces, diverging from silo-based functioning [69]. The broad support of OH by international organizations (FAO, OIE, WHO) and national governments, particularly after devastating outbreaks like HPAI (2003), Ebola (2014), and the new coronavirus (2019), underscores the necessity for cross-sector collaboration [70]. The FAO-OIE-WHO Tripartite Commitment paper highlighted the need to comprehend local elements for efficient OH operationalization in the poultry sector. India faces significant zoonotic challenges as a global "hotspot" with a vast human and livestock population [71]. Rapid socio-ecological and environmental changes contribute to high disease resurgence, prompting responses to outbreaks and emphasizing the need to address new epidemics. The Sustainable One Health approach in the Indian poultry sector aims to mitigate zoonotic risks by integrating animal, human, and environmental health. This approach entails implementing stringent biosecurity measures, enhancing vaccination protocols, and monitoring the health of both poultry and workers. Moreover, promoting reduced antimicrobial use, responsible waste management, and biodiversity enhances the restoration of ecosystem health and reduces zoonotic disease prevalence. Education and awareness play pivotal roles in the Sustainable One Health approach by involving stakeholders in understanding zoonotic risks and sustainable practices. Incorporating technology for disease surveillance and fostering a holistic approach that acknowledges the interconnectedness of human, animal, and environmental health are essential. The growth of OH in the poultry sector is contingent upon prior activities, environmental conditions, relational dynamics, and problem framing. Dynamic leadership, partner trust, institutional flexibility, resource availability, and effective communication are crucial for effective collaboration in the poultry sector [72]. The One Health approach in India addresses antimicrobial resistance, zoonotic diseases, and food safety, backed by comprehensive policies and regulations promoting cross-sector collaboration [73]. Specific local goals shape collaborative efforts within the poultry sector and necessitate individual skills, organizational structures, cultural aspects, and effective communication. Capacity building addressing zoonotic diseases, public health concerns, environmental degradation, and policy development is crucial. A well-functioning OH system within the poultry industry can manage emerging infectious zoonotic diseases and protect livestock populations [74]. Effective risk communication, early identification of infections, and investments in public health systems are vital. Multidisciplinary and cross-sectoral approaches are imperative for disease prevention, surveillance, control, and mitigation. Collaboration and investment in public health systems, particularly in the poultry industry, will strengthen surveillance infrastructure for emerging zoonotic diseases [75].

CONCLUSION

The poultry sector in India deals with the health and well-being of millions of poultry birds, farmers and farm workers, consumers, and other associated humans and the environment. Besides acting as a critical source of livelihood and nutrition, especially for the marginal communities of this country in the far-flung areas, the sector also presents a concerning interface for zoonotic disease transmission, raising significant public health concerns. This review article delved into the intricate interplay between zoonoses and the Indian poultry industry, examining the challenges posed and the potential for the One Health approach to offer sustainable solutions. This review revealed the complex dynamics underlying zoonotic diseases within the Indian poultry sector, where factors such as intensification, poor

biosecurity measures, and human-animal-environment interactions converge to heighten the risk of disease emergence and spread. Avian influenza, Salmonellosis, and Campylobacteriosis could stand out among the prevalent zoonoses, underscoring the urgent need for comprehensive strategies to mitigate their impact on public health, animal welfare, and environmental well-being. A vivid description of the zoonoses scenario of India to the poultry sector and available mitigation strategies were cited through the above sections. The system approach should be streamlined under a well-structured framework with supportive implementation machinery involving intersectional stakeholders from different sector strata. Strengthening the monitoring system with strict compliance with sectoral policy implementation could be an inseparable part of this framework to secure ground success in preventing zoonoses, thereby ceasing the chance of forthcoming pandemic situations. Also, it emerged from the factual discussion that any strategy related to the prevention and control of zoonoses in the poultry sector of India should invariably include the poultry bird health and welfare aspect as an apex component.

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