A thesis submitted in the partial fulfilment of the requirements for the degree of Master of Science in Applied Veterinary Epidemiology

Disease assessment and antimicrobial prescription patterns by analyzing web-based data set in Sonali Chicken cases at Bogura, Bangladesh in 2020-2021

Dr. Md. Ibrahim Khalil

Roll No: 0220/ 05

Registration No: 917

Session: 2020-2021

Chattogram Veterinary and Animal Sciences University (CVASU)
Chattogram -4225, Bangladesh

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Dr. Md. Ibrahim Khalil, DVM, MS, FETPV

March 2023

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This Master's thesis is found to be satisfactory in all aspects for evaluation

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Supervisor

Md. Ahasanul Hoque, PhD

Professor, Department of Medicine and Surgery
Faculty of Veterinary Medicine
Chattogram Veterinary and Animal Sciences University, Bangladesh

....

Course director of Field Epidemiology Training Program for Veterinarians (FETPV)

Prof. Dr. Sharmin Chowdhury
Director, One Health Institute
Chattogram Veterinary and Animal Sciences University, Bangladesh

Chattogram Veterinary and Animal Sciences University (CVASU)
Chattogram -4225, Bangladesh

Acknowledgements

At first, I would like to express my deepest gratitude to **The Almighty Allah** for giving me strength and opportunity to complete the research and thesis successfully for the degree of **Master of Science**, MSc, in **Applied Veterinary Epidemiology** under the One Health Institute, Chattogram Veterinary and Animal Sciences University (CVASU), Bangladesh. Secondly, I would like to express the first and foremost heartiest appreciation, deepest sense of gratitude and best regards to my supervisor **Prof Dr. Md. Ahasanul Hoque**. His cordial supervision and important suggestions helped me complete this thesis. It was great my pleasure and great experience to work with him.

I feel much pleasure to convey my profound thanks to the website owner **Dr. Mithun Sarker,** Upazila Livestock Officer, Kulaura, Moulovibazar, for his kind support to give access on the website dataset.

It is also my immense pleasure to give thanks to **Prof Dr. Sharmin Chowdhury**, Director, One Health Institute, CVASU, **Dr. TABM Muzaffar Goni Osmani**, Deputy Director (Epidemiology Unit), Department of Livestock Services (DLS), Bangladesh and **Dr Nurul Islam**, Technical coordinator, and **Dr. Sahidur Rahman**, Technical officer, Global Health Development (GHD) for valuable advice, scholastic guidance, inspiration and well thought suggestions during my study period.

Very special thanks to **Dr. Md. Abu Shoieb Mohsin,** Epidemiologist, GHD, **Dr. Nurun Nahar Chisty,** GCRF One Health Poultry Hub, Bangladesh and other fellows of Field Epidemiology Training Program for Veterinarians for their help and support.

I would like to give thanks to Prof **Dr. AMAM Zonaed Siddiki,** Co-coordinator of Advanced Studies and Research , CVASU, for his administrative support in relation to the thesis approval.

I want to acknowledge the authority of DLS, One Health institution and GHD for their cordial help during my research work and giving opportunity to enroll to FETPV.

Finally, I am ever indebted to my beloved parents, my wife for their immense sacrifice, spontaneous blessings and encouragement.

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Abbreviations	Elaborations
AB	Antibiotics
AHCAB	Animal Health Companies Association, Bangladesh
AMR	Antimicrobial Resistance
AMU	Antimicrobial Usages
BAHIS	Bangladesh Animal Health Intelligence System
BPICC	Bangladesh Poultry Industries Central Council
BVPGI	Bangladesh Veterinary Postgraduate Institute
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
CDC	Centers for Disease Control and Prevention
CIAs	Critically Important Antimicrobials
CRD	Chronic Respiratory Disease
CVASU	Chattogram Veterinary and Animal Sciences University
DLO	District livestock Officer
DLS	Department of Livestock Services
ECTAD	Emergency Centre for Transboundary Animal Diseases
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GPS	Global Positioning System
IB	Infectious Bronchitis
IBD	Infectious Bursal Disease
IEDCR	Institute of Epidemiology Disease Control And Research
KAP	Knowledge, Attitude, Practices
LPAI	Low Pathogenic Avian Influenza
LRI	Livestock Research Institute
MS	Master of Science
MSD	Merck Veterinary Manual

- ND Newcastle Disease
- NE Necrotic Enteritis
- NGOs Non-Government Organizations
- OHPH One Health Poultry Hub
- OECD Organization for Economic Co-operation Development
- OR Odds Ratio
- OTC Oxytetracycline
- RIR Rhode Island Red
- U2C Upazila to Community
- WHO World Health Organization
- WPSA World's Poultry Science Association
- WOAH World Organization for Animal Health
- % Percentages
- ≥ Greater than or equal to
- ≤ Less than or equal to
- 95% CI 95% Confidence Interval

Abstract

Bangladesh's poultry sector is crucial for economic development and nutrition demand fulfillment. Among all poultry species, Sonali chicken production is becoming popular due to its similar appearance and flavor to the local indigenous chickens. However, prevalent diseases and recurring outbreaks of several prevalent diseases and recurring outbreaks of infectious diseases hampered average poultry growth. The persistence of diseases is related to different management and environmental factors. To reduce disease load, irrational and inappropriate use of antimicrobials is commonly prescribed, contributing to the development of antimicrobial resistance (AMR). The current study investigated to map diseases and associated drivers, as well as evaluate antibiotic prescription patterns against diseases in Sonali chickens in Bogura district, by analyzing data stored on the newly developed website (bdvets.com). A total of 1690 drug prescriptions for diseases and disease conditions in Sonali chickens in Bogura during 2020–2021 were extracted from the e-prescription database of 3769 poultry cases for the present study. Data extracts were entered into MS Excel and cleaned and sorted before exporting to STATA/SE-13 for epidemiological analysis. The present study identified more cases in the center sub-districts of Bogura (40.3 %, n=681) than in other sub-districts the year 2020 (69.2 %, 1170) than in 2021 and during the summer (45.3%, 530 in 2020 and 39.2%, 204 in 2021) and winter (24.8%, 290 in 2020 and 33.1%, 172 in 2021) than autumn and rainy seasons. The study explored 24 distinct poultry diseases and conditions in single or concurrent cases. The proportion of cases were dominated by mixed diseases of viral, bacterial, and other infectious cases (28 %, 474), followed by viral diseases (17.5 %, 296), bacterial diseases (4.5 %, 76), and protozoan diseases (4.0 %, 67). The predominant single cases were necrotic enteritis, salmonellosis, colibacillosis, Newcastle disease (ND), Infectious Bursal Disease (IBD), Infectious Laryngotracheitis (ILT), Low Pathogenic Avian Influenza (LPAI) and coccidiosis. The occurrence of ND increased significantly during the rainy season (Odds Ratio: 2.1) and in the year 2021 (Odds Ratio: 2.4). Antibiotics were widely prescribed regardless of case type (84.4–97% of cases). The highest proportion of antimicrobials was used in protozoan cases (97 %, 65), followed by viral alone (92%, 273), mixed (91.7%, 435), and bacterial alone (90.8%, 69). Single antibiotics (61.3%, 980) were prescribed widely, followed by combined (14%, 224) and double (2.4%, 39). Tylvalosin (42%, 669) was more commonly prescribed for almost all disease types. Different fluoroquinolones and florfenicol were prescribed predominantly for bacterial cases (16%, 11). Colistin combined (3.4%, 55) was also prescribed. Moreover, antiviral drugs were prescribed for 33.5% of viral cases. Immuno-stimulant was prescribed for 18% of viral and bacterial cases.

The findings of the current investigation through a web-based data recording system provided baseline evidence about prescribers' perceptions of using antibiotics against different diseases. They offered insights into designing interventions in the DLS existing data recording system (BAHIS) and policies for using antimicrobials in Bangladesh.

Keywords: Antimicrobial Pattern, Disease Status, Recording System, Risk Factors,

Sonali Chicken, Web-based Data

Chapter-I: Introduction

The Bangladesh poultry subsector, a total of 375 million poultry and around 90000-100000 commercial farms supported by 610 animal health companies, 30 pharmaceuticals, 18 grandparent, 299 parent, 84 hatcheries, 293 registered feed mills (Hamid et al., 2017; Rahman et al., 2017b; BPICC, 2022; DLS, 2022b; WPSA-BB, 2022; AHCAB, 2022; The vet executive secretary, Dr. Bishwajit Roy, 2022: Personal communication), is crucial for supporting agricultural development and reducing malnutrition of the country (Hamid et al., 2017). It is an important component of Bangladesh's agricultural system, generating 20% direct and 50% indirect jobs and support services (DLS, 2022). Thirty-seven percent of Bangladesh's total meat production is obtained from poultry. The poultry sector also provides 136 eggs/ head/ year, exceeding the national demand (DLS, 2022a).

Bangladesh has multiple poultry production systems: conventional rural backyard scavenging, semi-scavenging, commercial credit, cash, and contracted or integrated farming (BPICC, 2022). Before industrialization, backyard poultry in Bangladesh was the only source of local, low-yielding, and nondescript birds, and it mostly met the demand of the producer's family (Ahmed et al., 1985). With the introduction of White Leghorn, Rhode Island Red (RIR), Fayoumi, Sonali, and Rupali in backyard chicken farming, Bangladesh's backyards have also undergone substantial changes in parallel with the development in the industrial poultry industry (Rahman et al., 2017b). Sonali (meaning "golden") is a crossbred chicken (*Gallus domesticus L.*) developed by crossing an RIR cockerel with a Fayoumi hen; it has a similar appearance and flavour to the local indigenous chickens (Islam et al., 2021b).

Despite this growth in poultry production, productivity is hampered by disease incidence and recurrent outbreaks of several infectious diseases. Due to the disease outbreak, Bangladesh experienced an annual chicken death rate of over 30% (Al-Mamun et al., 2019).

The documented diseases of commercial poultry sector in Bangladesh were Mycoplasmosis (68.8%; Ali et al., 2015 and 12.2%; Rahman et al., 2017a), Infectious Bronchitis (59.3%, Bhuiya et al.,2019), Infectious Coryza (0.08%; Al Mamun et al.,2019), Infectious Bursal Disease (IBD) (10.8%; Abdullah et al.,2019), Newcastle Disease (ND) (14.7%; Talukder et al.,2017), Marek's (9.3%; Rahman et al.,2017), colibacillosis (6.7%; Hassan et al., 2016) and Salmonellosis (38.6%; Hassan et al., 2016), Avian Influenza (2.6%; Hassan et al., 2016), Coccidiosis (5.7%; Hassan et al.,2016), fowl cholera (3.1%; Moryani et al., 2020) and Necrotitis Enteritis (NE) (1.6%; Hassan et al., 2016). Persistence of a wide range of poultry diseases were reported to be happened due to poor farm hygiene and bio-security, poor vaccine coverage, lack of maintaining vaccine cold chain, dead bird's disposal system, frequency of cleaning, isolation of ill hens, water supply, environmental and managerial stress, etc. (Singla et al., 2007; Belgard et al., 2018; Al-Mamun et al., 2019).

Although mapping diseases in different poultry species is available, exploration of poultry diseases or disease conditions in Sonali chickens is not commonly performed. In addition, the utilization of disease data recorded in the newly developed website (DLS, 2022: Personal communication; bdvets.com website owner, Dr. Mithun Sarker: Personal communication) to map diseases along with associated drivers in Sonali chicken is the first in Bangladesh. Hence, the present study is justified to conduct.

Antibiotics are widely used in commercial poultry production for different purposes (therapeutic, prophylactic, and growth promoters). Commonly used antibiotics in poultry in Bangladesh are reported as follows: i) under **access group**: amoxicillin and sulfamethoxazole-trimethoprim (18.5% and 32.5%; Imam et al., 2020), ampicillin, gentamicin, and cephalexin (1.4%, 7% and 1%; Rahman et al.,2019), doxycycline (20.6%; Islam et al.,2016); ii) **watch group**: azithromycin, oxytetracycline, neomycin, and pefloxacin (1.4%, 4.1%, 2.7%, 2.7%, respectively; Islam et al.,2016), ciprofloxacin and norfloxacin (22.5% and 1.7%; Ferdous et al.,2019), erythromycin (28.9%; Abdullah et al.,2019), levofloxacin (12%; Rahman et al., 2019), iii) **reserve group**: colistin (3.5%; Rahman et al., 2019), and polymyxin B (31.5%; Islam et al., 2016).

In Bangladesh, one-third of commercial poultry farmers use antimicrobials suggested by different non-vet prescriber groups (Hassan et al., 2021). Non-veterinarians or quacks used antibiotics despite being incapable of clinical diagnosis, as advised by antimicrobial suppliers, particularly feed and chick traders who work closely with drug company representatives to achieve sales goals (Imam et al., 2020). Non-professionals' indiscriminate use of antimicrobials promotes the spread of Antimicrobial Resistance (AMR) and results in economic, production, and other losses. Registered veterinarians also prescribe antibiotics mostly based on a presumptive diagnosis of different poultry diseases, therefore, there is a likely chance to occur inappropriate antibiotic prescription and thus pose the risk of becoming unsuccessful treatment and developing antibiotic resistance.

Although field veterinarians prescribe antibiotics widely for managing poultry diseases therapeutically across the country, there is little, or no study conducted to assess the pattern of antibiotic prescription for poultry diseases. This ground, therefore, suggested conducting the present study to evaluate antibiotic prescription patterns in diseases or disease conditions in Sonali chickens in Bogura district by analysis drug data maintained in the newly developed website (DLS, 2022 Personal communication; bdvets.com owner, Dr. Mithun Sarker, 2022: Personal communication).

We also assess the usefulness of the newly developed online disease and prescription data recording web site (bdvets.com owner, Dr. Mithun Sarker, 2022: Personal communication), which could be the supportive information system with added value for the existing Bangladesh Animal Health Intelligence System (BAHIS).

1.1. Objectives of the study

Based on the above background, the present study was designed with the following objectives.

1. Assess disease burden and pattern in Sonali chickens through the web-based data recording system maintained by the veterinary practitioners in Bogura, Bangladesh.
2. Determine factors associated with the most common poultry in Bogura, Bangladesh.

3. Assess the antimicrobial prescription (including those required for human use) patterns against different poultry diseases.

Chapter-II: Review of Literature

The goal of this chapter was to review the previous relevant published and unpublished articles to pin down the scientific gaps and accordingly justify the current Master's research. Literatures were obtained by searching online sources like PubMed, Google Scholar, and Web of Science. Unpublished articles or official reports were obtained through personal communication. This chapter is arranged in a series of sections, including Bangladesh poultry industry, poultry farming challenges, animal disease information system, poultry disease surveillance, web-based animal/poultry diseases data and its challenges, BAHIS), emergence of bdvets.com for data recording in livestock in Bangladesh, poultry diseases and associated drivers, poultry disease prevention and control, diagnosis facilities, antibiotics uses in poultry, consequence of poultry diseases and antibiotic uses and the summary of the literature review.

2.1. Poultry industry in Bangladesh

The Bangladeshi poultry subsector is essential for promoting agricultural growth and reducing malnutrition (Da silva et al.,2013). It is a major aspect of Bangladesh's agricultural system and has created 20% direct and 50% indirect employment opportunities and support services (DLS, 2022a). This subsector has demonstrated its value to the economy by becoming an attractive economic activity. It has contributed 1.9% to the total gross domestic product (GDP) (DLS, 2022a). The sector accounts for 14% of the total value of livestock production (Hamid et al.,2017). It has been determined that 37% of Bangladesh's total meat production is comprised of poultry meat. However, per capita consumption of animal protein from poultry is lower as compared with any of neighbour countries (6.3 kg in Bangladesh vs. 6.6 kg in Pakistan, 48.7 kg in Malaysia, 7.8 kg in Indonesia, 7.8 kg in Thailand, 14 kg in China, 16.2 kg in Vietnam, 17.7 kg in Japan and 18.7 kg in Korea) (Kawsar et al., 2013; WPSA, 2017; OECD, 2020). Recently, Bangladesh become sufficient in egg production (23.35 billion eggs in 2020-21 against 17.85 billion egg demand (DLS, 2022a).

The growth of poultry sectors is supported by 293 DLS-registered feed mills,610 animal health companies, 11 poultry companies, 30 pharmaceuticals, 18 grandparents, 299 parent, 84 hatcheries, and other relevant stakeholders (Hamid et al., 2017; Rahman et al., 2017b; BPICC, 2022; DLS, 2022; WPSA-BB, 2022; AHCAB, 2022; The vet executive secretary, Dr. Bishwajit Roy, 2022: Personal communication; PhD student, University of Queensland, Jinnat Ferdous, 2022: Personal communication).

Bangladesh has different poultry farming systems like traditional rural backyard scavenging, semi-scavenging, commercial credit, cash, and contracted or integrated farming (BPICC, 2022). Before industrialization, backyard poultry in Bangladesh was the only source of local, low-yielding, and unremarkable birds, and it mostly satisfied the producer's family's demand (Ahmed et al.,1985). As the business has adopted new breeds/varieties/strains, advanced housing and equipment, and effective marketing strategies, industrial poultry has dominated the entire supply of chicken meat and eggs. Government initiatives, the participation of a few Non-Government Organizations (NGOs) and entrepreneurs, and changes in the country's socioeconomic situation over the past two to three decades have all contributed to this broader and significant shift in the Bangladeshi poultry industry (Raha et al., 2013).

Cobb 500, Ross 308, Indian River Meat, Tiger Sasso, Habbard, and Arber acre are Bangladesh's most prevalent broiler strains. Novogen Brown/White, Hyline Brown/White, Shaver 579, ISA Brown, Hi-Sex Brown/White, and Bovine White are the most frequent layer strains. Along with transformations in industrial poultry, Bangladesh's backyard production system has changed significantly by introducing White Leghorn, RIR, Fayoumi, Sonali, and Rupali in backyard chicken farming (Rahman et al.,2017b).

Sonali (meaning golden) is a crossbred chicken (*Gallus domesticus L.*), developed with the cross between an RIR cock and a Fayoumi hen that has a similar appearance and taste to the local indigenous chickens (Islam et al.,2021b). It was initially introduced in the northern regions of Bangladesh between 1996 and 2000, generating work opportunities for tens of millions of rural women (Uddin et al.,2015). Later on, Sonali chicken started to rear in commercial farming systems and is being increased in volume and now spreads all over the country (Uddin et al., 2015).

2.2. Poultry farming challenges in Bangladesh

Despite many opportunities and benefits of poultry rearing in Bangladesh, there are numerous obstacles in this sector, such as a lack of sustainable development policies and their implementation, multiple infectious diseases, poor poultry disease surveillance and data management systems, ineffective disease prevention and control measures, insufficient veterinary services, excessive reliance on feed dealers, and unstable market prices (Kawsar et al., 2013; Rahman et al., 2015; Msoffe et al., 2016; Masud et al., 2020). Large-scale industries' monopolies and high-priced products are also disadvantages. Excessive or indiscriminate use of antibiotics in chickens without following any treatment protocol is also a key challenge causing antibiotic resistance, posing a potential threat to public health (Chowdhury et al., 2021).

2.2.1. Animal disease information system in Bangladesh

In Bangladesh, there is no structured, systematic, and sensitive disease surveillance system to collect all the disease data of animal health. Upazila (sub-district) Livestock Offices maintain patient registry data to report to the higher authority of the Department of Livestock Services (DLS), which has many limitations. In addition, the DLS has a few donors driven projects through which Pestedes Petits Ruminants, Foot and Mouth, anthrax, and rabies data are being collected (DLS, 2022: Personal communication). BAHIS, a digital system, has also been introduced in 2019 to record animal disease information in this country (DLS, 2022: Personal communication).

2.2.2. Poultry disease surveillance in Bangladesh

Poultry disease data are produced through donor-supported surveillance and research activities on limited diseases like avian influenza, ND, and food-borne pathogens of poultry origin (Abdullah et al., 2019; Rimi et al., 2019; One Health Poultry Hub, Prof Md. Ahasanul Hoque, 2022: Personal communication). Moreover, the DLS has no mechanism to collate poultry disease data from different sources (poultry companies, academic institutes, research organizations, private practitioners etc.).

2.2.3. Web-based animal/poultry diseases data and its challenges

Formerly, obtaining disease data relied on a hierarchy of health experts, which can be costly to build and maintain, resulting in a delay or a halt in reporting (Iannetti et al.,2014). However, web-based disease data recording systems add a new dimension to epidemiology by utilizing technology to collect, organize, and disseminate data more promptly. By searching for information from both formal sources, partially and completely automated systems enable the earlier detection of disease outbreaks. Web-based applications display diverse information online or send it to subscribers or the public via e-mail. Individuals, humanitarian organizations, and government health and veterinary departments now utilize these platforms, which continue to develop (Madoff et al.,2014). Examples of web-based recording systems for animal and human diseases in various countries are presented in **Table 2.1**.

Table 2.1. Different animal and human diseases web-based recording systems in different countries

Surveillance name	Org. /Country	Diseases name	Ani-mal	Hu-man	Ref.
One Health disease surveillance	Tanzania	Zoonotic disease	Yes	Yes	Karimuribo et al. (2014)
Web-based bio-portal system in animal disease surveillance	Sweden and Denmark	Avian Influenza	Yes	-	Willenberg et al. (2006)
China Information system for disease control and prevention	China	Priority animal and poultry diseases	Yes	Yes	Wang et al. (2013)
Web-based disease surveillance(PCD software)	IEDCR, Bangladesh	Communicable and zoonotic diseases (Anthrax and Rabies)	-	Yes	IEDCR, (2022a)
Bangladesh Animal Health Intelligence System(BAHIS)	DLS, Bangladesh	Livestock diseases (Very poor data of poultry)	Yes	-	DLS, (2022: Personal communication)

Surveillance name	Org. /Country	Diseases name	Ani-mal	Hu-man	Ref.
World Animal Health Information system	WOAH, Worldwide	OIE listed animal diseases including zoonotic and emerging diseases	Yes	-	Madoff et al. (2014)
Web-based geographic information system	Italy	Highly contagious animal diseases and poultry diseases	Yes	-	Savini et al. (2007)
National animal disease reporting system	India	Economic-ally important livestock and poultry diseases, zoonotic diseases	Yes	-	Kumar et al. (2021)

Currently, web-based data recording systems are better able to detect outbreak information in countries with high levels of internet access. However, developing countries often have limited resources for functioning web-based data recording systems (Chretien et al.,2008). The sensitivity and specificity of web-based surveillance is often unclear (Madoff et al.,2014). Trained personnel should verify information, who should also utilize advanced techniques such as machine learning to help organize data.

2.2.4. Bangladesh Animal Health Intelligence System (BAHIS)

BAHIS is a system established by the FAO Emergency Centre for Transboundary Animal Diseases (ECTAD) and the DLS and launched in 2019. BAHIS is an information system that will ensure timely field reporting and analysis of received data to aid in the control and prevention of animal diseases (DLS, 2022: Personal communication).

The system can perform basic data analysis and produce outcomes based on the analysis. In addition, it is an early warning system designed to notify decision-makers via "Alert Messages" of significant epidemiological occurrences at the sub-district (Upazila) level.

Over time, the monitoring system tracks the prevalence of DLS-prioritized disorders (DLS, 2022: Personal communication).

BAHIS is a passive surveillance system in which patient registry data are input and kept in a central database system to detect animal disease outbreaks by evaluating data from only government veterinary hospitals. It is augmented by large and small animal data and Upazila to Community (U2C) reporting data, a participatory method to disease searching. The information regarding poultry disease data was, however insufficient to detect epidemics of poultry diseases in BAHIS (DLS, 2022: Personal communication), and there are many reasons behind such as a low number of poultry veterinarians at Upazila Livestock Offices, lack of interest to store data, epidemiological knowledge and data management system, etc. The poultry sector is dominated by poultry companies which have their private veterinarians. Data recorded through veterinarians of those companies are not forwarded to the DLS. However, there is no integrating system in Bangladesh to amalgamate all the data of private companies into government bodies. A web-based poultry disease recording data along with drug prescription data privately run by veterinarians in the selected part of Bangladesh (bdvets.com owner, Dr. Mithun Sharkar, 2022: Personal communication:) can supplement, to some extent, the central system of the DLS.

2.2.5. Emergence of bdvets.com for data recording

A field veterinarian "Dr. Mithun Sharkar" introduced bdvets.com, a web-based data recording system, for the first time in Bangladesh in 2019. He enthusiastically developed the website and made it accessible to all veterinarians to facilitate reporting. A total of 876 veterinarians are now utilizing the website across the country. Using this platform, a registered veterinarian can compose an online veterinary e-prescription. The device data recording system is recently recognized by the DLS and Ministry of Information and Communication Technology (National digital award-2022) as a useful recordkeeping method for livestock and poultry health care services. The website supports "Android Mobile Applications" with blood donation, internet marketing, social media, and farmers training (Video classes) (bdvets.com owner, Dr. Mithun Sharkar, 2022: Personal communication). Poultry disease data and drug data generated through this system, were considered for this MS research.

2.3. Poultry diseases and associated factors

2.3.1. Poultry diseases occurrence

Frequent outbreaks of different types of diseases hamper the productivity of poultry. About 30% of chickens' mortality occurred in Bangladesh every year due to different infectious disease incidences (Al-Mamun et al., 2019). Among bacterial diseases, Fowl cholera (3.1%; Moryani et al., 2020), Infectious Coryza (0.08%; Al Mamun et al.,2019), Salmonellosis (38.6%; Hassan et al.,2016), Necrotic enteritis (1.6%; Hassan et al.,2016) and Colibacillosis (8.3%; Moryani et al.,2020) are common. Among viral diseases, Avian Influenza (2.6%; Hassan et al., 2016), ND (11.2%; Talukder et al.,2017), Infectious Bronchitis (59.3%, Bhuiya et al.,2019), IBD (10.8%; Abdullah et al.,2019) and Marek's disease (9.3%; Rahman et al.,2017a) are more frequent. However, Coccidiosis (5.7%; Hassan et al.,2016), Mycoplasmosis (68.8%; Ali et al., 2015 and 12.2%; Rahman et al., 2017), Chronic Respiratory Disease (CRD) (4.9%, Al Mamun et al.,2019) etc. are also happening round the year. Moreover, mixed infections (26%; Tipu et al., 2021) are also very common in Bangladesh.

2.3.2. Factors associated with common poultry diseases

The occurrence of poultry diseases in a particular area depends on factors like geo-climatic condition, bird population, management practices, immunization etc. (Al-Mamun et al., 2019).

Moreover, different factors are associated with different disease such as multiple species on the same farm (species with different susceptibilities to the virus), the presence of animals of different ages, low vaccination coverage, vaccine failure etc. are also significant risk factors in the spread of infectious diseases (Belgard et al.,2018). Frequency of cleaning, isolation of birds, dead birds' disposal system, water source etc. were found to be substantially correlated with the disease occurrence (Belgard et al., 2018). However, backyard production systems had a substantially larger prevalence than small-scale commercial operation systems (Tilahun et al., 2021). Floor disinfection between production cycles dramatically reduced the likelihood of positive cases (Mo et al., 2016). Excessive litter wetness, immunological suppression, and environmental and managerial stress all contribute to epidemics of clinical cases (Singla et al., 2007). Over the last few years, several emerging diseases and unknown causes have threatened the poultry industry and caused huge losses to farmers. The burden of different poultry diseases needs to be estimated scientifically to prevent and control the diseases. Therefore, the study was conducted to assess the status of various infectious diseases in Sonali chickens using the previously reported web data.

2.4. Prevention and controls of poultry diseases

Maintaining stringent hygiene and biosecurity practices, along with successful immunization and appropriate medicine, can minimize the overall infection burden on a farm and diminish the risk to the lowest extent possible (Das et al.,2008). FAO (Food and Agriculture Organization) and WOAH (World Organization for Animal Health) define biosecurity as the adoption of measures to prevent the introduction and spread of disease organisms (FAO, 2005). Although methods of classifying these measures may vary, they all refer to the same fundamental principles of bioexclusion (i.e., preventing infectious agents from entering the farm) and biocontainment (i.e., preventing infectious agents from leaving the farm (Charisis et al.,2008) and were implemented via: segregation to increase barriers to infectious diseases, cleaning, and disinfection (FAO,2005). These are two principles: (i) isolation, which ensures no contamination of flocks through housing and personal protection equipment; (ii) traffic control, which restricts the movement of products, stocks, and people; and (iii) sanitation, which includes methods for farmers to maintain disinfection and cleanliness in flocks (Conan et al.,2012). However, these principles are impractical in Bangladesh's socio-economic context. In Bangladesh, the biosecurity practices on commercial poultry farms are generally inadequate. People can access commercial poultry farms without disinfecting their shoes, clothes, or equipment. In addition, wild birds can enter poultry sheds, wild and domestic animals commonly roam farm grounds, and chicken waste disposal is frequently ineffective (Imam et al., 2021).

Moreover, a vaccination schedule is maintained to prevent common diseases. When purchasing day-old chicks from breeder farms or hatcheries, small farmers typically receive instructions on vaccination and treatment to protect their birds from disease (Conan et al.,2012). In Broiler and Sonali production in Bangladesh, Mareks’ disease vaccine is used during 0-1 days of age from breeder farms or hatcheries, followed by Baby Chick

Ranikhet Disease Virus (i.e., ND Virus) used in days 3-5, IBD in 10-12 days and Ranikhet Disease Virus Vaccine (ND Virus) in 17-21 days. After 60 days of rearing, booster doses of ND vaccine are used (LRI, 2022 and MSD, 2022). The poultry birds to be vaccinated against diseases may not respond effectively to vaccines due to the following shortcomings, thus resulting in vaccine failure such as stress on birds, concurrent disease, immunosuppressive diseases, cold chain maintenance, immaturity of birds, interaction with maternal antibodies, improper route of administration etc. (Sharif et al., 2018).

2.5. Diagnosis facilities of common poultry diseases in Bangladesh

The diagnosis of different diseases at the field level is based on the clinical history, clinical signs, and gross and microscopic examinations by registered veterinarians working in different settings and non-veterinarians (e.g., feed dealers) (Badruzzaman et al., 2015).

Sometimes, laboratory diagnosis is performed through government and non-government laboratories in Bangladesh. Specific test kits are primarily used for the diagnosis of diseases. Sometimes, diseases are confirmed by isolating and identifying causal agents (Harrigan et al.,1998). For viral diseases, several types of serological tests are performed (Badruzzaman et al.,2015).

2.6. Antibiotics uses in poultry

Antibiotics are widely used in commercial poultry for different purposes in Bangladesh: i) therapeutic, ii) prophylactic, and iii) growth promotion. Commonly used antibiotics in poultry in Bangladesh are reported as follows: i) under **access group**: amoxicillin and sulfamethoxazole-trimethoprim (18.5% and 32.5%; Imam et al.,2020), ampicillin, gentamicin, and cephalexin (1.4%, 7% and 1%; Rahman et al.,2019), doxycycline (20.6%; Islam et al.,2016); ii)**watch group**: azithromycin, oxytetracycline, neomycin, and pefloxacin (1.4%, 4.1%, 2.7%, 2.7%, respectively; Islam et al.,2016), ciprofloxacin and norfloxacin (22.5% and 1.7%; Ferdous et al.,2019), erythromycin (28.9%; Abdullah et al.,2019), levofloxacin (12%; Rahman et al., 2019), iii) **reserve group**: colistin (3.5%; Rahman et al., 2019), and polymyxin B (31.5%; Islam et al., 2016).

Inappropriate antimicrobial prescriptions can lead to AMR (Hockenhull et al., 2017). However, in Bangladesh, one-third of commercial poultry farmers use antimicrobials given to them by different non-veterinary prescriber groups such as dealers and local expert farmers (Hassan et al., 2021). Poultry farmers are bound to local feed and drug sellers who enable indiscriminate access to antibiotics to commercial poultry farmers, who use these products on their schedules, largely without veterinary supervision (Kalam et al., 2022). Moreover, there are distinct policy and implementation gaps in the veterinary sector, such as the inclusion of AMR in the veterinary curriculum and proper prescribing guidelines for the veterinarians' appropriate use of antimicrobials in the livestock sector (Orubu et al., 2020). Both hampered implementing the proper strategies for judicious use of antimicrobials (MoHFW, 2017). However, DLS has developed treatment guidelines for poultry for the first time in collaboration with FAO-ECTAD, which are ready to be distributed to all practitioners in Bangladesh (DLS, 2022: Personal communication). The prudent use of antimicrobials is crucial to prevent resistance development, and this can be achieved by introducing changes in prescribing behavior and the AMR KAP of prescribers (Kalam et al., 2022).

2.7. Consequence of poultry diseases and antibiotic uses

2.7.1. Consequence of poultry diseases

An outbreak of disease has a very high negative economic impact on the flock as well as for the poultry producer, as treatment alone cannot prevent economic losses (Mohammed et al., 2015). It is also estimated that the economic losses due to ND alone is about US $ 288.5 million annually in Bangladesh (Khatun et al., 2018). The losses associated, including the cost of control measures and production losses. The diseases, therefore, carry losses for the farmer through mortalities, reduced market value of the affected birds, and sometimes culling or delayed slaughter time (Mohammed et al., 2015).

Moreover, different poultry diseases like Avian influenza (Bird flu), ND, campylobacter, salmonellosis, avian tuberculosis, colibacillosis etc. can be transmitted from poultry to humans (Dale et al., 2013; Whitehead et al., 2014; Hogerwerf et al., 2020; Hossain et al., 2021). These zoonotic disease outbreaks are enhanced due to unconscious animal-trading markets, farms presence in the residence area, working in the farm without protection etc., every year in Bangladesh (Dale et al., 2013; Chowdhury et al., 2021).

2.7.2. Consequence of antibiotic uses

A large diversity of antimicrobials is used to raise poultry in most countries, including Bangladesh. Many such antimicrobials are considered to be essential in human medicine. The indiscriminate use of such essential antimicrobials in animal production is likely to accelerate the development of AMR gene in pathogens, as well as in commensal organisms. This would result in treatment failures and economic losses and could act as a source of gene pool for transmission to humans (Agayre et al., 2018). In addition, there are human health concerns about antimicrobial residues in meat, eggs, and other animal products (Goetting et al., 2011). Generally, when an antibiotic is used in any setting, it eliminates the susceptible bacterial strains, leaving behind those with traits that can resist the drug. These resistant bacteria then multiply and become the dominating population and, as such, can transfer (both horizontally and vertically) the genes responsible for their resistance to other bacteria (Agayre et al., 2018).

2.8. Summary of literature review

From the above review, we can conclude that there are some studies on poultry disease distribution and antimicrobial prescription patterns in Bangladesh. They used survey and/or patient registry data from sub-district level livestock hospitals, which might have validation problems due to the lack of a structured poultry disease and antibiotic use data-keeping system in Bangladesh. Those create gaps in terms of assessing poultry disease distribution and prescription patterns. To fill these gaps, newly launched web-based poultry data recording systems are an inevitable option. Therefore, the present study assessed the incidence of Sonali chicken diseases along with their epidemiological distribution and antimicrobial prescription patterns by analyzing web-based surveillance data given by a veterinarian in their prescriptions. The intended findings are believed to serve as a baseline for future researchers. They could support the government's animal information system to detect disease outbreaks in real-time and evaluate the appropriate use of antimicrobial agents under an antimicrobial stewardship approach.

Chapter-III: Materials and Methods

3.1. Study area description

Bogura, the driest district Northwestern climatic zone, is called the gateway of North Bengal, located between 24º32´ and 25º07´N and 88º58´ and 89º45´E (Khan et al., 2019), with an area of 2898.68 sq. km (BBS, 2022). This district has featured different rivers, beels, low and high land, and diverse ethnic groups (Muslim, Hindu, and Christians and a range of tribes). The population size of this district is 3,734,300, with a population density of 1288 sq. km (BBS, 2022). This district constitutes 12 Upazilas (sub-districts). The literacy rate of this district is 72.4% (BBS, 2022). According to the data from the Bangladesh Bureau of Statistics in 2022, the predominant occupations in this district are farming, with general commerce, customer service, transportation, wage labor, and various other industries following closely behind. The average annual dry bulb temperature, maximum and minimum temperature, rainfall, and humidity in 2020 and 2021 were 25.8°C, 37.8°C, 7.7°C, 1855 mm, and 76% (Bangladesh Meteorological Department, Climate Division, Dhaka, 2022: Personal communication).

Enlisted Poultry farm distribution of Bogura is 4,80,494 deshi chicken household farms, 1870 broiler farms, 1620 Sonali farms, 1123 layer farms, 584 duck farms, 8 breeder farms, and 67 hatcheries (District Livestock Officer, Bogura, Dr. Md. Saiful Islam, 2022: Personal communication).

3.2. Description of the website and the data set

3.2.1. Description of the website

bdvets.com is a web-based data recording system first introduced by Dr. Mithun Sarker, Government Field Veterinarian, in 2019. He launched the website with his own interest and opened it for all public and private veterinarians to make disease reporting easier. Currently, 876 veterinarians across the country are registered on this website. The DLS has recently recognized the website as a valid and useful recording system for livestock and poultry health care services. The website includes blood donations, online marketing, social media, and educational services.

3.2.1.1. Flow of data collection of bdvets.com

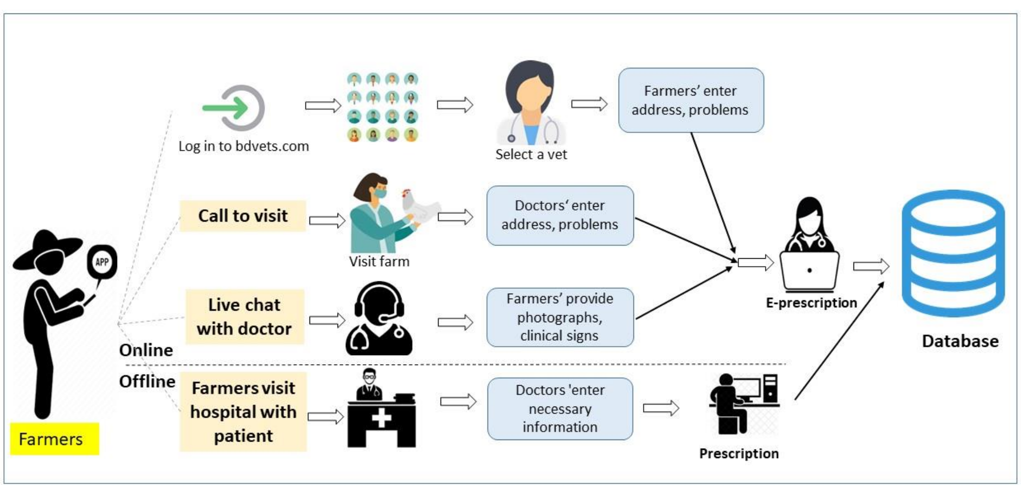
The **bdvets.com** data recording system allows farmers to access veterinary services online and offline. After logging in and providing some basic information, farmers can select a veterinarian from the list for receiving services. A farmer can also call a veterinarian to visit their farm or request an e-prescription. Patient data (disease, demography, drugs, and other pertinent data) are stored in the website's farm database. However, farmers can only view prescription data.

The live chat feature is another way to acquire online services. Farmers can use the live chat veterinary care service by providing patient photographs, clinical signs, and other relevant information.

Farmers can also get similar services via audio or video calls. In this situation, the data are saved in a different database, and veterinarians deliver the prescriptions to the farmers.

For offline services, farmers bring their animals to the veterinarian, who enters the necessary information into the database and prints a prescription.

Figure 3. 1. Flowchart of data collection of bdvets.com



3.2.2. Description of the dataset

With permission from the website administrator, we retrieved all Sonali and Broiler chicken cases with prescriptions in Bogura and other districts recorded on the website from November 2019 to March 2022 for the study. Bogura has 1714 and 406 Sonali and Broiler cases with their epidemiology and prescription data. In contrast, other districts have 481 and 326 cases with their epidemiology and prescription data (**Details in Appendix-I**). However, we used the records of Sonali chicken cases with epidemiology and prescription data obtained from Jan 2020 to Dec 2021 due to completeness and a sufficient number of cases for the study.

Data available in the web-based recording system include related farmers' and case demographic (species, production type, age), flock size, number of affected and dead birds, location (GPS data), clinical history (owners' complaints, date of illness, number of sick and dead birds and history of medicine use), clinical signs, necropsy findings, and diagnosis.

Registered veterinarians diagnosed cases based on clinico-epidemiological history, clinical signs, and lesions. Exposure variables were measured by asking questions to individual client farmers as well as by observing the individual cases. Climate data were collected from the Bangladesh Meteorological Department (BMD, 2022).

3.3. Data management and analysis

3.3.1. Data management

Web data extracts in MS Excel 2010 sheets were cleaned, sorted, coded, and recorded before exporting to STATA/SE-13 for epidemiological analysis.

3.3.2. Descriptive analysis

We conducted a descriptive analysis of the data set to calculate the frequency distribution of cases by Upazilas, time and climate characters (temperature, humidity, and rainfall), rearing stage, and flock size. Distribution of cases by different disease groups and years were counted simultaneously. The Fisher's exact test was conducted to assess the difference in the proportion of cases by factors between 2020 and 2021.

Moreover, we generated a frequency distribution of different drug categories (antimicrobials, antiviral, immune stimulant, pre- and probiotics, enzymes and miscellaneous supportive drugs) by a group of poultry diseases (bacterial, viral, mixed etc.). We counted the antimicrobial frequency by case type. Results are expressed in frequency numbers, percentages, graphs and p value.

3.3.3. Risk factors analysis

3.3.3.1. Univariate logistic regression

Fisher's exact test was performed to identify risk factors for the binary response variable (ND: Yes/No). The factors considered for the univariable analysis were year (2020 and 2021)), season (winter, summer, rainy, and autumn), age (starter and grower), flock size (small and medium, large), temperature (≥25°C and <25°C), humidity (≥75%, <75%), and rainfall (≥29 mm and <29 mm).

3.3.3.2. Simple Logistic regression

Factors significance in Fishers' exact test ($p \leq 0.05$) were used to conduct univariate logistic regression. For each factor variable, the results were provided as an odds ratio (OR), a p-value, and a 95% confidence interval.

3.3.4. Spatial analysis

Google maps (https://www.google.com.bd/maps) was used to get the study area of data collection. ArcGIS-ArcMap version 10.2 (ESRI, USA) was used to produce a map of the frequency of cases by location under the study.

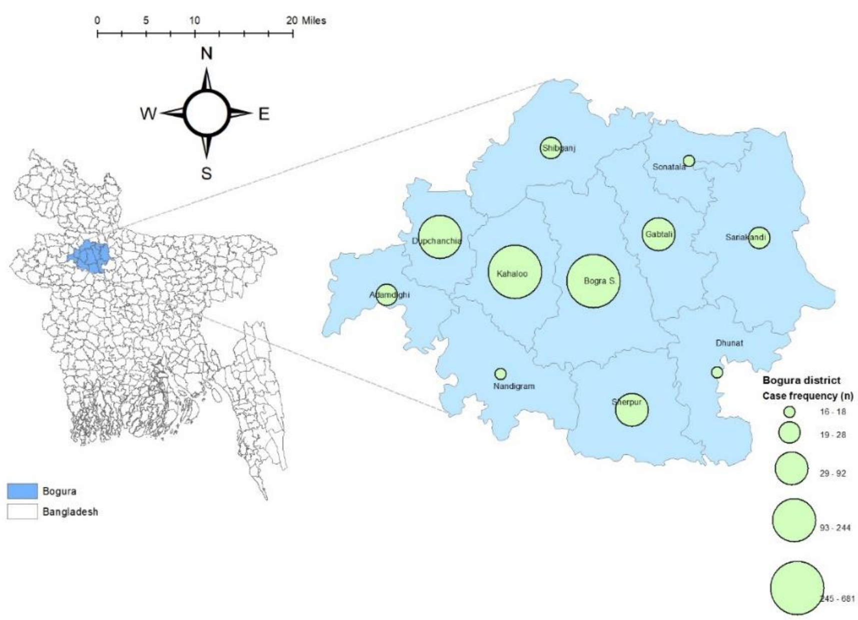
Chapter IV: Results

4.1. Distribution of Sonali chicken cases in Bogura

4.1.1. Distribution of cases by Upazila (sub-district)

The distribution of Sonali chicken cases in different Upazilas of Bogura is presented in **Figure 4.1**. Sonali chicken cases were more frequent in Bogura sadar (40.3%, 681) followed by Kahaloo (28.2 %, 477) and Dhupchanchia (14.4 %, 244). Cases of other Upazilas were as follows: Sahajanpur (5.3 %, 90), Gabtali (4.1%, 69), Shibganj (1.7%, 28), Adamdighi (1.5%, 26), Sariakandi (1.4%, 23), Sonatola (1.1%, 18), Dhunat (0.9%, 16), Nandigram (0.9%, 16) and Sherpur sub-district (0.1%, 2).

Figure 4. 1. Distribution of Sonali chicken cases in different Upazilas presented in the map.



4.1.2. Distribution of cases by time (N=1690)

More Sonali chicken cases were recorded in 2020 (69.2%, 1170) than in 2021 (30.8%,520).

More cases were recorded during Summer (45.3%, 530 in 2020 and 39.2%, 204 in 2021) and winter (24.8%, 290 in 2020 and 33.1%, 172 in 2021). Autumn and Rainy had similar case patterns but less frequent cases (13.7%, 160 in 2020 and 14.3%, 74 in 2021 vs. 14%, 164 in 2020 and 15.6%, 81 in 2021, respectively) **(Figure 4.2)**.

However, the almost identical pattern of case occurrence was evidenced from March to July (23.2%, 272 Mar, 12.5%, 146 Apr, 9.6%, 112 May, 8.5%, 100 Jun and 3.3%, 39 Jul in 2020 vs. 15.4%, 80 Mar, 8.6%, 45 Apr, 15.2%, 79 May, 9.8%, 51 Jun and 2.9%, 15 Jul in 2021 and September to December (3.0%, 35 Sep, 5.3%, 62 Oct, 6.0%, 70 Nov and 5.6%, 66 Dec in 2020 and 3.1%, 16 Sep, 5.4%, 28 Oct, 5.2%, 27 Nov, and 5.2%, 27 Dec in 2021) (**Figure 4.3**). However, a different pattern was found in January to February (2.5%, 29 and 16.7%, 195 in 2020 and 15%, 78 and 12.9%, 67 in 2021) and August (3.8%, 44 in 2020 and 1.3%, 7 in 2021) (**Figure 4.3**).

Figure 4. 2. Frequency distribution of Sonali chicken cases in Bogura by season and year (N=1690).

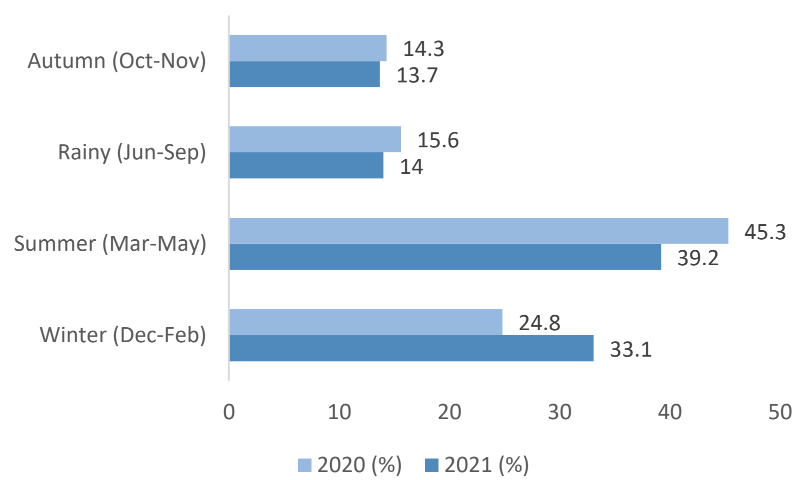
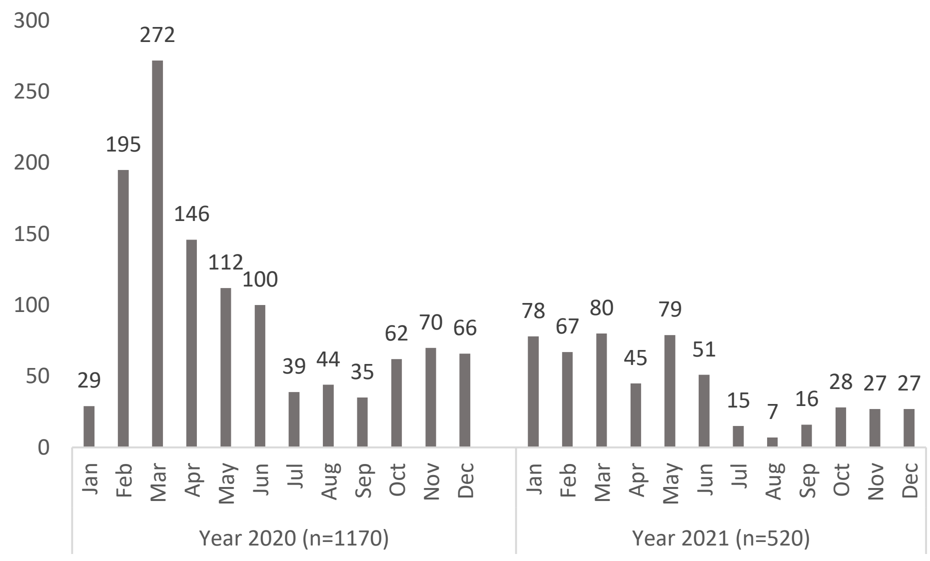


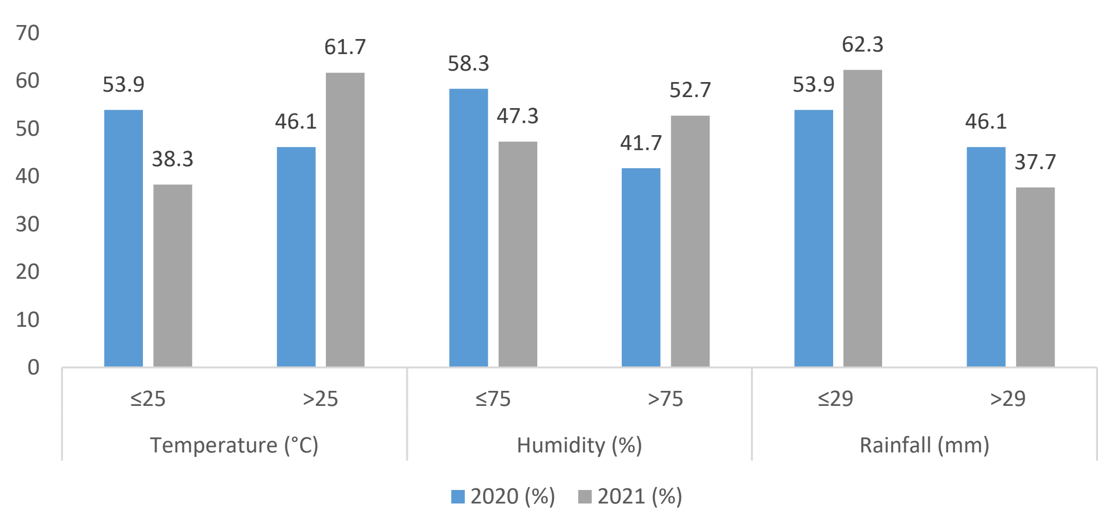
Figure 4. 3. Distribution of Sonali chicken cases in Bogura by time (N=1690).



4.1.3. Distribution of cases by climate characters (N=1690)

In 2020, higher number of cases were found at ≤25°C (53.3%), ≤75% humidity (58.3%), and >29 mm rainfall (46.1%) compared to the counterpart of each variable. Conversely, in 2021, a greater number of cases were found at >25°C (61.7%), >75% humidity (52.7%), and ≤29 mm rainfall (62.3%).

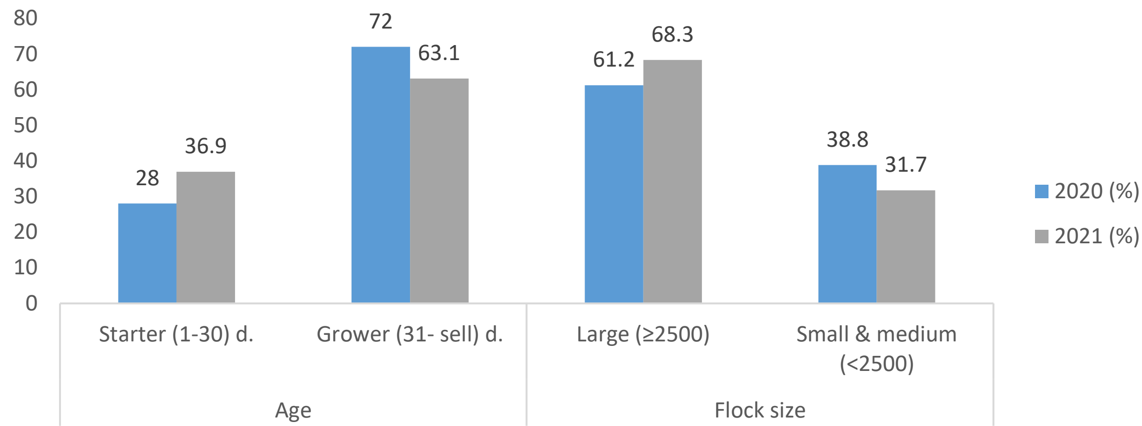
Figure 4. 4. Distribution of Sonali chicken cases in Bogura by climate characters (N=1690)



4.1.4. Distribution of Sonali chicken cases in Bogura by rearing stage and flock size (N=1690)

Most cases were recorded during the grower stage and in larger flocks (72% and 61.2%, respectively in 2020) and (63.1% and 68.3%, respectively, in 2021).

Figure 4.5. Distribution of Sonali chicken cases in Bogura by rearing stage and flock size in 2020 and 2021.



4.2. Distribution of diseases in Sonali chicken in Bogura

The proportion of cases was dominated by mixed (bacterial, viral diseases etc.) (28%, n=474), followed by viral diseases (17.5%, 296), bacterial diseases (4.5%, 76), protozoan disease (4.0%, 67) and miscellaneous diseases (5.3%, 90). A total of 40.7 %, (n=687) cases were undiagnosed **(Table 4.1)**.

The proportion of viral cases was significantly higher in 2020 (20.3%, 237) than in 2021 (11.3%, 59) (p=0.001). However, the proportion of bacterial cases was significantly greater in 2021 (10%, 52) than in 2020 (2%, 24) (p <0.001). Similarly, a significantly greater proportion of other case groups was estimated in 2021: protozoan (12.8%, 67 vs. 0%, p<0.001), miscellaneous (9.6%, 50 vs. 3.4%, 40; p<0.001), mixed infections (56.2%, 292 vs., 15.6%, 182; p<0.001).

Among bacterial cases, Necrotic Enteritis (NE) (2.1%, 35) was more common, followed by Salmonellosis (1.5%, 25) and colibacillosis (0.9%, 16). By year the proportion of

Salmonella cases was significantly higher in 2021 (4.2%, 22) than in 2020 (0.3%, 3) (p<0.001). A significantly higher proportion of *E.Coli* cases was estimated in 2021 (2.7%, 14) than in 2020 (0.2%, 2) (p <0.001).

Among viral cases, ND ranked the first position (13.9%, 235) followed by Low Pathogenic Avian Influenza (LPAI) (2.7%, 46), Infectious Bursal IBD (0.3%, 5), and Infectious Laryngotracheitis (ILT) (0.3%, 5). However, only the proportion of ND cases was significantly higher in 2020 (16.6%, 194) than in 2021 (0.3%, 3) (p<0.001).

Coccidian cases were only recorded in 2021 (12.8%, 67).

Among miscellaneous cases, Enteritis hold the top position (4.5%, 76) followed by CRD (0.3%, 5), Gout (0.2%, 4), and Mycoplasmosis (0.2%, 3). The proportion of Enteritis cases was significantly higher in 2021 (8.1%, 42) than in 2020 (2.9%, 34) (p<0.001). The proportion of CRD cases was significantly greater in 2021 (0.8%, 4) than in 2020 (0.8%, 4) (p=0.034).

Among mixed cases, Mareks, along with other cases, stood first (12.7%, 214) followed by ND plus (11%, 186) and coccidiosis along with other cases (2.4%, 40). As compared to 2020, the proportion of cases was significantly higher in 2021 for Mareks' disease (24.2%, 126 vs. 7.5%, 88; p<0.001) and ND (19%, 99 vs. 7.4%, 87; p<0.001).

Table 4. 1. Distribution of cases in Sonali chicken in Bogura by disease group and year.

Sl. No	**Catagories**	**Disease name**	**Total (N=1690)**	**2020 (N=1170)**	**2021 (N=520)**	**P value (Fisher's exact)**
			% (n)	**% (n)**	**% (n)**	
1	**Bacterial diseases**	Colibacilosis	0.9 (16)	0.2 (2)	2.7 (14)	**0.000**
		NE	2.1 (35)	1.6 (19)	3.1 (16)	0.064
		Salmonellosis	1.5 (25)	0.3 (3)	4.2 (22)	**0.000**
		Total	**4.5 (76)**	**2.0 (24)**	**10.0 (52)**	**<0.001**
2	**Viral diseases**	*IBD	0.3 (5)	0	1.0 (5)	**0.003**
		*ILT	0.3 (5)	0.3 (4)	0.2 (1)	1.000
		*LPAI	2.7 (46)	3.0 (35)	2.1 (11)	0.336

Sl. No	Catagories	Disease name	Total (N=1690) % (n)	2020 (N=1170) % (n)	2021 (N=520) % (n)	P value (Fisher's exact)
		*ND	13.9 (235)	16.6 (194)	7.9 (41)	**0.000**
		Miscellaneous	0.3(5)	0.3 (4)	0.2 (1)	1.000
		Total	**17.5 (296)**	**20.3 (237)**	**11.3 (59)**	**0.001**
3	**Protozoan disease**	Coccidiosis	**4.0 (67)**	0	12.8 (**67**)	**0.000**
4	**Miscellaneous**	CRD	0.3 (5)	0.1 (1)	0.8 (4)	**0.034**
		Enteritis	4.5 (76)	2.9 (34)	8.1 (42)	**0.000**
		Gout	0.2 (4)	0.3 (3)	0.2 (1)	1.000
		Mycoplasmosis	0.2 (3)	0.2 (2)	0.2 (1)	1.000
		Others symptoms	0.1 (2)	0	0.6 (2)	0.293
		Total	**5.3 (90)**	**3.4 (40)**	**9.6 (50)**	**0.001**
5	**Mixed**	Coccidiosis mixed	2.4 (40)	0	7.7 (40)	**0.000**
		Colibacillosis mixed	0.2 (4)	0	0.8 (4)	**0.009**
		IBD mixed	0.7 (11)	0	2.1 (11)	**0.000**
		ILT mixed	0.2 (4)	0.2 (2)	0.4 (2)	0.591
		LPAI mixed	0.3 (5)	0.2 (2)	0.6 (3)	0.173
		ND mixed	11.0 (186)	7.4 (87)	19.0 (99)	**0.000**
		NE mixed	0.2 (3)	0	0.6 (3)	**0.029**
		Mareks mixed	12.7 (214)	7.5 (88)	24.2 (126)	**0.000**
		Salmonellosis mixed	0.2 (3)	0.1 (1)	0.6 (3)	0.089
		Miscellaneous mixed	0.2 (3)	0.2 (2)	0.2 (1)	1.000
		Total	**28.0 (474)**	**15.6 (182)**	**56.2 (292)**	**<0.001 (Chi)**
6	**Undiagnosed**		**40.7 (687)**	**687**	**0**	

(*IBD= Infectious Bursal Disease, *ND= New Castle, *LPAI= Low Pathogenic Avian Influenza, *ILT= Infectious Laryngotracheitis). **Mixed category**: a major disease associated with other bacterial, viral, other diseases (Based on the clinical signs and importance of diseases). **Miscellaneous viral diseases category**: included IBH=Inclusion Body (n=1), Fowl pox (2) and High Pathogenic Avian (HPAI) (2). **Miscellaneous other symptoms category**: included weakness (1) and anorexia (1). **Undiagnosed category**: cases were counted individually.

4.3. Risk factor analysis

4.3.1. Univariate association for Newcastle Disease (ND)

The occurrence of ND in Sonali chickens varied significantly by year, season, age, temperature, rainfall, and humidity ($p \le 0.2$, Fisher's exact test) (**Table 4.2**). These variables were therefore forwarded to construct the multivariate logistic regression.

Table 4. 2. Association between Newcastle disease and each of the selected factors.

Variables	Categories	ND positive n (%)	ND negative n (%)	p (Fisher's exact test)
Year	2020	281 (24.0)	889 (76.0)	0.101
	2021	145 (27.9)	375 (72.1)	
Season	Winter (Dec-Feb)	201 (43.5)	261 (56.5)	<0.001
	Summer (Mar-May)	154 (21)	580 (79)	
	Rainy (Jun-Sep)	56 (21.9)	200 (78.1)	
	Autumn (Oct-Nov)	15 (6.3)	223 (93.7)	
Age	Starter (1-30) days	153 (29.4)	367 (70.6)	**0.009**
	Grower (31-upto sell) days	273 (23.3)	897 (76.7))	
Flock size	Small & Medium (≤2500)	270 (25.2)	801 (74.8)	1.000
	Large (≥2500)	156 (25.2)	463 (74.8)	
Temperature	≥25°C	305 (36.8)	525 (63.2)	<0.001
	<25°C	121 (14.1)	739 (85.9)	
Humidity	≥75%	307 (33.1)	621 (66.9)	<0.001

Variables	Categories	ND positive n (%)	ND negative n (%)	p (Fisher's exact test)
	<75%	119 (15.6)	643 (84.4)	
Rainfall	≥29 mm	335 (35.1)	620 (64.9)	<0.001
	<29 mm	91 (12.4)	644 (87.6)	

4.3.2. Simple logistic regression

Multivariate logistic regression was attempted to construct. However, the model did not fit well according to the goodness of fit test (p>0.05). Therefore, only simple logistic regression was used.

The odds of ND cases were significantly higher in 2021 than in 2020, with an odds ratio (OR) of 1.6 (p< 0.001) and rainy season than winter (OR=2.4; p< 0.003). The odds of ND cases were significantly lower in the starter compared with the grower stage (OR=0.7; p=0.011), Summer (OR=0.5; p=<0.001), and autumn (OR=0.1; p<0.001) than winter, <25°C temperature than ≥25°C (OR=0.4; p=0.001), and <75% humidity compared to ≥75%(OR=0.3; p<0.001).

Table 4.3. Simple logistic regression between Newcastle disease and the significant risk factors (p≤0.2, Fisher's exact test).

Variables	Categories	OR	95% CI	p
Age	Grower(31-upto sell) days	1	**Ref**	
	Starter(1-30) days	0.7	0.6, 0.9	0.011
Year	2020	1	**Ref**	
	2021	1.6	1.1, 2.1	0.001
Season	Winter (Dec-Feb)	1	**Ref**	
	Summer (Mar-May)	0.5	0.4, 0.8	0.000
	Rainy (Jun-Sep)	2.4	1.4, 4.2	0.003

Variables	Categories	OR	95% CI	p
	Autumn (Oct-Nov)	0.1	0.1, 0.2	0.000
Temperature	≥25°C	1	**Ref**	
	<25°C	0.4	0.2, 0.7	0.001
Humidity	≥75%	1	**Ref**	
	<75%	0.3	0.2, 0.5	0.000

4.4. Drug prescription pattern

4.4.1. Distribution of prescribed drugs by case types

Antibiotics were widely prescribed regardless of case type (84.4% to 97% of cases). The highest proportion of antimicrobials was used in protozoan cases (97 %, 65), followed by viral single (92%, 273), mixed (91.7%, 435), and bacterial single (90.8%, 69).

Antiviral drugs were prescribed for 33.5% viral, 33% bacterial, and 30% protozoan cases. Immuno-stimulant was prescribed for 18% viral and bacterial cases. Pre-probiotic enzymes and other miscellaneous drugs were also prescribed for different case types **(Table 4.4).**

Table 4.4. Distribution of different drugs prescribed in Sonali chicken cases in Bogura by case types.

Category	Total cases (N=1690) %(n)	Bacterial Single (n=76) %(n)	Viral Single (n=296) % (n)	Protozoan Single (n=67) % (n)	Mixed diseases[2] (n=474) % (n)	Undiagnosed (n=687) % (n)	Miscell aneous[3] (n=90) % (n)
Antimicrobials[1]	89.3 (1509)	90.8 (69)	92.2 (273)	97.0 (65)	91.7 (435)	86.0 (591)	84.4 (76)
Antiviral	36.2 (612)	32.8 (25)	33.5 (99)	29.9 (20)	42.8 (203)	31.7 (218)	52.2 (47)
Immune stimulant	14.7 (249)	18.4 (14)	17.9 (53)	19.4 (13)	12.5 (59)	13.7 (94)	17.8 (16)

Category	Total cases (N=1690) %(n)	Bacterial Single (n=76) %(n)	Viral Single (n=296) % (n)	Protozoan Single (n=67) % (n)	Mixed diseases[2] (n=474) % (n)	Undiagnosed (n=687) % (n)	Miscellaneous[3] (n=90) % (n)
Pre- and Probiotics	22.1 (374)	26.3 (20)	21.6 (64)	11.9 (8)	21.7 (103)	23 (158)	23.3 (21)
Enzymes	10.1 (170)	6.6 (5)	7.8 (23)	16.4 (11)	11.2 (53)	9.0 (62)	17.8 (16)
Miscellaneous supportive drugs[3]	76.2 (1287)	76.3 (58)	89.2 (264)	74.6 (50)	80.8 (383)	68.7 (472)	66.7 (60)

[Antiviral drug was acyclovir and Immuno stimulants were Lisovit, Immolyte etc.1=Diclazuril, Nicarbazin, Sulfachloropyrazine and Others Antimicrobial 2= Mixed (Bacterial+Viral+Others/any mixed disease conditions);3=Detoxifier, Acidifier, Antigout, Zinc, Multivitamin, Kidney care, minerals, digestive stimulant and antipyretic drugs.]

4.4.2. Types of antimicrobial prescribed

4.3.2.1. Distribution of antimicrobials prescribed in Sonali chicken cases in Bogura by case type

Single antibiotics (61.3%, 980) were prescribed widely, followed by combined antibiotics (14%, 224) and double antibiotics (2.4%, 39) in different case types. Fluoroquinolones (9.1%, 145) was prescribed commonly across different case type. However, more frequent was for bacterial cases (10%, 7). Florfenicol was predominantly prescribed for bacterial cases (16%, 11). Tylvalosin (42%, 669) was more commonly prescribed for almost all disease types except bacterial cases alone (1.5%, 1).

Among combined preparation, colistin combined (3.4%, 55) was prescribed highly, followed by aminoglycosides combined (2.4%, 38). The highest proportion of Colistin was prescribed for bacterial cases (7.3%, 5) followed by undiagnosed cases (4.2%, 25), viral (3.6%, 10) and mixed cases (3.5%, 15). Aminoglycoside was primarily prescribed for bacterial cases (7.3%, 5).

Among antiprotozoal drugs, Diclazuril (24.6%, 16) and Nicarbazin (33.8%, 22) were frequently prescribed for protozoan cases. However, Sulfachloropyrazine was prescribed for bacterial cases (24.6%, 17).

Different fluoroquinolones (9.1%, 145), colistin plus (3.4%, 55), colistin with other antibiotics (0.1%, 2) like critically important antimicrobials for human were prescribed in Sonali chicken prescription. Fluoroquinolones stood first against undiagnosed case type (11.8%, 70) followed by mixed (10.1%, 44), bacterial (10.1%, 7), viral (8.4%, 23) and protozoan (1.5%, 1) groups. In addition, tylvalosin (41.8%, 669), tylosin (3.6%, 58), tilmicosin (0.4%, 6), tylosin plus (0.3%, 5), and tylvalosin with other antibiotics (1.3%, 21) like critically important antimicrobials for only veterinary use were used irrespective of case types.

In cases of tylvalosin usage, the largest percentage, 69.6% (190), is attributed to viral cases, followed by mixed cases at 47.1% (205), undiagnosed cases at 44.9% (265), protozoan cases at 12.3% (8), and bacterial cases at 1.5% (1). In contrast, the highest proportion of tylosin used in mixed (5.9%, 7) and undiagnosed groups (3.9%, 23) followed by bacterial (2.9%, 2) and viral single (2.6%, 7) cases.

Table 4. 5.Frequency distribution of antimicrobials used in Sonali chicken in Bogura by different disease types.

Categories	**Name/Group/Class**	**Total cases (N=1600)**	**Bacterial Single** (n=69)	**Viral Single** (n=273)	**Protozoal Single** (n=65)	**Mixed Diseases** (n=435)	**Undiagnosed** (n=591)
		%(n)	**%(n)**	**%(n)**	**%(n)**	**%(n)**	**%(n)**
Single antibiotic	Aminoglycosides	2.6 (42)	2.9 (2)	0.7 (2)	1.5 (1)	4.8 (21)	2.7 (16)
	Amoxicillin	0.2 (3)	0	0	0	0	0.5 (3)
	Cephalosporin	0.1 (1)	0	0	0	0	0.2 (1)
	Florfenicol	2.0 (32)	15.9 (11)	0	1.5 (1)	0.9 (4)	2.7 (16)
	*Fluoroquinolones	9.1 (145)	10.1 (7)	8.4 (23)	1.5 (1)	10.1 (44)	11.8 (70)
	Sulfa	0.9 (14)	0	0.4 (1)	7.7 (5)	0.7 (3)	0.9 (5)
	Tetracycline	0.6 (10)	0	0	0	1.2 (5)	0.9 (5)
	*Tilmicosin	0.4 (6)	1.5 (1)	0.4 (1)	1.5 (1)	0.5 (2)	0.2 (1)
	*Tylosin	3.6 (58)	2.9 (2)	2.6 (7)	0	5.9 (26)	3.9 (23)
	*Tylvalosin	41.8 (669)	1.5 (1)	69.6 (190)	12.3 (8)	47.1 (205)	44.9 (265)
	Total	**61.3 (980)**	**34.8 (24)**	**82.0 (224)**	**26.2 (17)**	**71.3 (310)**	**68.5 (405)**
Antiprotozoan	Diclazuril	2.1 (34)	4.4 (3)	0.7 (2)	24.6 (16)	1.4 (6)	1.2 (7)
	Nicarbazin	5.7 (91)	8.7 (6)	5.9 (16)	33.8 (22)	5.1 (22)	4.2 (25)
	Sulfachloropyrazine	3.8 (61)	24.6 (17)	1.5 (4)	9.2 (6)	3.7 (16)	3.1 (18)

Categories	Name/Group/Class	Total cases (N=1600)	Bacterial Single (n=69)	Viral Single (n=273)	Protozoal Single (n=65)	Mixed Diseases (n=435)	Undiagnosed (n=591)
		%(n)	**%(n)**	**%(n)**	**%(n)**	**%(n)**	**%(n)**
	Others Antimicrobial	0.3 (4)	0	0	1.5 (1)	0	0.5 (3)
	Total	**11.9 (190)**	**37.7 (26)**	**8.1 (22)**	**69.2 (45)**	**(10.1) 44**	**9.0 (53)**
Combined preparation	Aminoglycosides (+)	2.4 (38)	7.3 (5)	1.8 (5)	1.5 (1)	3.2 (14)	2.2 (13)
	*Colistin (+)	3.4 (55)	7.3 (5)	3.6 (10)	0	3.5 (15)	4.2 (25)
	*Tylosin (+)	0.3 (5)	0	0.4 (1)	0	0.2 (1)	0.6 (4)
	Tetracycline (+)	2.0 (32)	4.4 (3)	0.4 (1)	0	2.3 (10)	3.1 (18)
	Lincosomide (+)	4.4 (70)	2.9 (2)	0.7 (2)	1.5 (1)	5.9 (26)	6.6 (39)
	Sulpha (+)	1.4 (23)	2.9 (2)	2.2 (6)	1.5 (1)	1.2 (5)	1.5 (9)
	Total	**14.0 (224)**	**9.2 (17)**	**9.2 (25)**	**0.2 (3)**	**16.3 (71)**	**18.3 (108)**
Two antibiotics	*Colistin & Other ab	0.1 (2)	-	-	-	-	0.3 (2)
	Aminoglycosides & Other ab	0.6 (9)	0	0.4 (1)	0	0.7 (3)	0.9 (5)
	*Tylvalosin & other ab	1.3 (21)	1.5 (1)	0.4 (1)	0	1.6 (7)	2.0 (12)
	Other combined ab & other ab	0.4 (7)	1.5 (1)	0	0	0	1.0 (6)
	Total	**2.4 (39)**	**2.9 (2)**	**0.7 (2)**	**0**	**2.3 (10)**	**4.2 (25)**

[Aminoglycosides were Gentamicin, neomycin and streptomycin, *= Critically important antimicrobials classified as per WHO Critically Important Antimicrobials for Human Medicine 6th revision, ab = antibiotic; Common fluoroquinolones were ciprofloxacin, levofloxacin, ofloxacin, nalidixic acid, pefloxacin, sparofloxacin. Tylvalosin derived from tylosin through the modification of 3-acetyl-4′-isovaleryl (acetylisovaleryltylosin tartrate]

Chapter-V: Discussion

The current study assessed the pattern of common diseases or disease conditions along with antimicrobial prescription patterns in Sonali chicken cases in Bogura. In this chapter, the study's significant findings, implications, limitations, conclusions, recommendations, and future directions have been thoroughly discussed under various headings as follows.

5.1. Cases recorded in the data recording system

The present study identified more cases in the center sub-districts of Bogura. The adoption of the online prescription system by veterinarians in the central sub-districts may be attributable to the region's highest proportion of cases. There were more reported cases in 2020 than in 2021, which could be due to technical challenges with the website, which necessitated an update in 2021. It is possible that the transfer of the veterinarians from that area, who contributed more, could be a reason for the decline in cases in 2021.

Moreover, in 2020, the government of Bangladesh implemented a countrywide lockdown in response to COVID-19 (IEDCR, 2022b). In that period, neither veterinarians nor farmers were permitted to roam, which could be a potential reason behind the increased number of cases in the digital data recording system in 2020.

More cases were estimated during the summer and winter seasons, independent of year, in the present study which are supported by previous studies conducted in India (Gowthaman et al., 2020) and Bangladesh (Badruzzaman et al., 2015). In contrast, some earlier studies reported more cases during the rainy season in Bangladesh (Rashid et al., 2013) and Trinidad (Nicole et al., 2000). Greater number of cases during the Summer and the Winter seasons were reported in this study, which could be due to the cause of birds' immunosuppression in heat stress (during Summer) (Bartlett et al., 2003; Niu et al., 2009; Lara et al., 2013) and cold stress (during Winter) (Chen et al., 2012).

In the current study, lower temperature, humidity, and precipitation all contributed to increased cases in 2020, and our results are in-lined with the findings of previous studies

(Nayak et al., 2015; Akagha and Nwagbara, 2021). Variations of these climatic characters in 2020, along with the considerable amount of time consumed for technical servicing and updating the web device in 2021 as well as movement restriction during COVID in 2020 (as discussed earlier) might have contributed to more cases in 2020.

The current investigation found that more cases were recorded in grower birds and bigger flocks. Our findings are congruent with those of Hailegebrea et al. (2022), Birhan et al. (2019), and Etuk et al. (2004), who reported more cases in grower and adult birds in Ethiopia and Nigeria. Abede et al. (2018) found more cases in between 3 to 8 weeks of age. Grower birds might have longer exposure time to be infected than younger ones (Mose et al., 2016). In addition, the space and management required for grower birds might have been compromised (Wakenell et al., 2016). Therefore, there were many cases in grower birds. More cases might be attributable to poor farm management of larger farms, and this result is in accordance with the earlier studies (Yunus et al., 2008; Yemane et al., 2016). In the case of Sonali chicken rearing in Bangladesh, farmers usually keep more birds in a small-sized shed, which is un-scientific, and likely increase the chance of more cases in birds from higher flock size.

5.2. Sonali chicken disease pattern

The study explored 24 distinct poultry diseases and disease conditions in single or concurrent, with the predominant cases of necrotic enteritis, salmonellosis, colibacillosis, ND, IBD, ILT, LPAI, and coccidiosis. Our findings are well-matched with many earlier studies in Sonali and other fowl in Bangladesh (Uddin et al., 2010; Badruzzaman et al., 2015; Hassan et al., 2016; Talukdar et al., 2017; Al Mamun et al., 2019; Islam et al., 2021a). Similar chicken disease patterns were reported in Nigeria, Pakistan, India, and Ethiopia (Balami et al. 2014; Abede and Gugsa, 2018).

The more cases of mixed diseases and viral disease alone in this study could be attributable to poor vaccination coverage, inappropriate vaccine usage, vaccine failure due to the cold chain, the subclinical condition of the diseases, or inadequate sanitary and biosecurity standards (Uddin et al., 2010; Sarkar et al., 2012). Generally, hygiene and biosecurity standards at Sonali chicken farm in Bangladesh are relatively poor (Rimi et al., 2017).

Salmonellosis, colibacillosis, and coccidiosis were more frequent in 2021 compared to 2020. These may be attributable to the effects of variations of climatic conditions (lower temperature, high humidity, etc., in 2021). However, coccidiosis is associated with litter management, where poor litter management increases the chance of coccidiosis incidence (Lawal et al., 2016).

In 2021, there were significantly more cases of enteritis, CRD, and Mareks mixed than in 2020. Overall, we had more cases in 2020. This is unclear why more cases of the diseases above in 2021 exist.

5.3. Risk factors for Newcastle Disease (ND)

The rainy season and 2021 significantly increased the occurrence of ND than their counterparts (Odds ratio of 2.4 and 1.6; $p<0.05$, respectively). Our findings are consistent with the findings of Rahman and Adhikary (2016). The rainy season might have provided more adverse conditions (high humidity, low temperature, reduced feed intake) that might have reduced the immune status of birds, thus making them more vulnerable to infections (Elijah et al., 2006; Hoque et al., 2012) and decreased production (Elijah et al., 2006). The reasons behind the occurrence of more cases of ND in 2021 are not clearly understood. Unfavorable weather conditions in 2021 could pose challenges for farmers to maintain a good litter management for their birds (Abede et al., 2018). However, the previous literature identified the factors associated with outbreaks of coccidiosis: litter moisture exceeding 30%, immune suppression, and environmental and management stress (Singla et al., 2007; Abede et al., 2018).

5.4. Prescription patterns in Sonali chicken cases

Antimicrobials were widely prescribed regardless of disease group (bacterial or viral or protozoal). Antibiotics can be used to compensate for poor farm biosecurity conditions and manage concurrent bacterial infections. Veterinarians usually diagnose poultry diseases based on clinical history, signs, and post-mortem lesions. Therefore, accurate diagnosis is not always possible. In such circumstances veterinarians prescribe antibiotics wrongly.

Antibiotics (Fluoroquinolones, Tylvalosin, Tylosin, colistin, and aminoglycosides combined) were prescribed in around 90% of viral disease cases in this study, which could be due to prevent secondary bacterial infection or concurrent bacterial diseases. Using antibiotics in poultry viral cases increases the chance of AMR (Hassan et al., 2021). Antibiotics are essential to protect poultry health, but their misuse creates a favorable niche for AMR bacteria in livestock farms, wildlife, and the environment, which might be transmitted to humans through contaminated foods or direct contact (Mund et al., 2017; Hassan et al., 2021; Tian et al., 2021). Nevertheless, it's worth noting that in a significant number of viral cases, immunostimulants (17.9%, n=53) and antiviral medications, including herbal remedies (33.5%, 99), were prescribed, indicating what appears to be sound and reasonable medical practices. The use of immunostimulants in viral cases may be the reason for boosting the immune response, which could result in enhanced growth rate and performance due to a reduction in the load of infectious causes and provide the opportunity for maximum performance (Abdel-Hafez and Mohamed, 2016; Iren et al., 2000).

Supplementation of pre- and pro-biotics in the diet can improve animal health and performance through contributions to gut health and nutrient use. For instance, supplementation of probiotics has been demonstrated to benefit farm animals in immune modulation, structural modulation, and increased cytokine production, which positively affect the intestinal mucosal lining against pathogens (Abd El-Hack et al., 2020). Several other feed additives are used, such as enzymes and organic acids, as supportive drugs (Bin-Jumah et al., 2020; Elgeddawy et al., 2020).

Prescribers used antibiotics (aminoglycosides, florfenicol, fluoroquinolones, tilmicosin, tylosin, tylvalosin) widely against bacterial cases in this study which are rationale. Our findings are consistent with the findings of Masud et al. (2020), Hassan et al. (2021), Tian et al. (2021), and Chowdhury et al. (2022). Single antibiotic use against bacterial cases might be possible due to the intuition of the veterinarian to diagnose cases through post-mortem and other clinical signs at the field level. Contrarily, Masud et al. (2020) found that multiple antibiotics were used in all farms for poultry throughout the production cycle.

The present study found that antibiotics were used against protozoan cases (Coccidiosis). The reason for using antibiotics in coccidian cases might be necrotic enteritis is intimately linked to intestinal lesions induced by coccidiosis in chicken (Cervantes et al., 2015). Furthermore, coccidiosis induces a local T cell-mediated inflammatory response that increases mucin (and mucous) production, ultimately favoring *C. perfringens* growth due to its mucolytic ability (Collier et al., 2003 and 2008). Opengart et al. (2005) and Cooper et al. (2009) found that lincomycin, bacitracin, oxytetracycline, penicillin, and tylosin were used in necrotic enteritis associated coccidiosis treatment. Furthermore, it is important to note that aside from Nicarbazin, the other remaining anticoccidials have limited long-term effectiveness and may lead to antibiotic resistance (Cervantes et al., 2015).

The current study found that different critical, highly critical and reserve group of antibiotics was used frequently. Tetracycline, amoxicillin, tilmicosin, tylosin, tylvalosin, and fluoroquinolones, like critically important antibiotics, were used, which should be preserved for critical cases only. Fluoroquinolone is also commonly prescribed in this study, which is considered a critically important antibiotic for human and animal health. Colistin was also prescribed in this study, a critically important antibiotic with the highest priority (Chowdhury et al., 2022; WHO, 2021) and reserve group drug of WHO AWaRe classification of antibiotic (WHO, 2021). To compensate for poor biosecurity conditions on farms and to manage concurrent bacterial infections, it may be possible to inspire the usage of antimicrobials. In addition, the recurrence of clinical symptoms may prompt practitioners to prescribe antimicrobials continuously. Prescribers may have trouble diagnosing diseases in the field. Laboratory confirmation of livestock, including poultry, diseases in Bangladesh is limited to district veterinary hospitals, regional field disease investigation laboratories, and the central disease investigation laboratory of the DLS (Imam et al., 2021).

The widespread use of animal and/or human health important or critically important antibiotics in commercial chicken production was also previously documented in Bangladesh (Imam et al., 2021; Rousham et al., 2021; Chowdhury et al., 2022), Pakistan (Umair et al., 2021), Philippines (Barroga et al., 2020), Vietnam (Choisy et al., 2019), Cameroon (Kamini et al., 2016), Tanzania (Nonga et al., 2009) and Ghana (Boamah et al., 2016). This massive use of medically significant antibiotics in commercial chicken farming may contribute to the evolution of AMR in microbial communities that infect animals and humans (Chowdhury et al., 2022).

The high burden of antibiotic use also shows a lack of compliance of treatment standards in the research area, as Bangladesh does not have adequate veterinary disease treatment guidelines. However, the DLS has recently developed a guideline collaboratively with FAO-ECTAD that can be helpful in reducing the indiscriminate use of antibiotics (DLS, 2022: Personal communication). In addition, the Bangladesh Veterinary Postgraduate Institute (BVPGI) has started training veterinarians to administer effective treatments to animals, which could aid in resolving the AMR issue (BVPGI founder, Dr. Nure Alam, 2022: Personal communication). Moreover, the Bangladesh government and NGOs have initiated the launch of AMR surveillance by following One Health approach, which helps to the antibiotic stewardship program (DLS, 2022: Personal communication). OHPH, Bangladesh has also been taking the initiative to make poultry farmers, veterinarians, and dealers aware of this risk of overuse of antibiotics and AMR through different training programs in Bangladesh (OHPH, Bangladesh, Prof Md. Ahasanul Hoque, 2022: Personal Communication).

5.5. Usefulness of the web-based data recording system

bdvets.com is an excellent system for recording disease data along with drug data, as evidenced by this study. This system will also substantiate the DLS's existing data recording system, BAHIS. However, some more epi data (more farm and farmer demography, biosecurity and management (e.g. vaccination), spatial and temporal, drug doses and duration) need to be incorporated in this system.

Using this recording system, a registered veterinarian can generate an electronic prescription for treating birds'. This stored data could be utilized to identify the burden of poultry disease and its associated factors to take suitable measures. Moreover, this information may be used for evaluating antibiotic prescribing trends over the time. An emerging or re-emerging infectious poultry disease can be identified in real-time via this data recording system, aiding in outbreak investigation and establishing disease surveillance.

5.6. Limitations of the study

This study only considered Sonali chicken cases within Bogura district. This is because there were a sufficient number of Sonali cases found in this area for this MS research. Incomplete epidemiological data was another limitation of this study. Different Sonali chicken cases were diagnosed based on clinical signs and post-mortem lesions. Information and recall bias might have occurred. However, registered and experienced veterinarians recorded the data.

Chapter-VI: Conclusion, Recommendations and Future direction

6.1. Conclusion

The findings presented in this study represent the current relative poultry disease prevalence and antimicrobial use patterns in the study area. This study recorded 24 different diseases in Sonali chicken. Commonly occurring diseases were necrotizing enteritis, salmonellosis, colibacillosis, ND, IBD, and coccidiosis. Colibacillosis mixed, salmonellosis, NE, IBD, ILT, IBD, LPAI, ND, and coccidiosis were frequent mixed diseases. ND cases were more prevalent during the growing stage of Sonali chicken, the rainy season, temperatures below 25 °C, relative humidity below 75%, and the year 2021. Prescribers used single and combined preparations of antibiotics against bacterial, viral, protozoal, and mixed cases. Antibiotics against viral and protozoal cases and critically important human antibiotic and reserve group drug use are the key drivers of growing AMR. However, immuomodulators, pre- and post-biotics against viral cases and are good practices all. In particular, the findings of the current investigation provided baseline evidence about prescribers' perceptions of using antibiotics against different diseases. They offered insights into designing interventions and policies for using antimicrobials in Bangladesh.

6.2. Recommendations

6.2.1. The study recommends arranging different farmers' training on biosecurity improvement and vaccination programs to reduce the disease burden.

6.2.2. In particular, the study strongly recommends including farmers and veterinarians in the policies to combat AMR. Hence, including educational and awareness efforts to increase the knowledge, favorable attitudes, and better practices of Antimicrobial usages (AMU) is highly recommended.

6.2.3. Veterinarians should be concerned not to use critically or highly critically important antibiotics and to use antibiotics with caution in viral cases.

6.2.4. In addition, the study encourages the use of immunostimulants, antiviral drugs, and herbal medicine in viral cases.

6.2.5. Overall, this study shows that this web-based surveillance could be part of the mainstream DLS to provide data from the field level after improving the system to have more epi data, which could help set up a real-time surveillance system.

6.3. Future directions

6.3.1. The current study was restricted to the Bogura district in Sonali chicken. So, any future study should consider other poultry species and wider geographical coverage.

6.3.2. Spatial and temporal patterns of common infectious studies could be taken.

6.3.3. Acceptability study of this newly launched system among farmers and other relevant stakeholders could be taken.

6.3.4. Antimicrobial Resistance pattern identifying study could be taken.

6.4. Outcomes

1. Identified important poultry diseases using the data obtained through the web-based recording system in Bogura of Bangladesh, for example, Necrotic Enteritis, Salmonellosis, colibacillosis, Newcastle Disease, Low Pathogenic Avian Influenza, Newcastle Disease mixed, Mareks mixed etc.
2. Determined antimicrobial prescription patterns by analyzing the drug data obtained through the web-based recording system in Bogura of Bangladesh, for example, Tetracycline, amoxicillin, tilmicosin, tylosin, tylvalosin, fluoroquinolones, colistin etc.

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Appendix-I

Table: Frequency distribution of cases reported in bdvets.com by districts in Bangladesh.

Year	Month	Bogura		Joypurhat		Gaibanda		Dinajpur		Rangpur		Narsingdi		Narayangonj	
		B	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**
2019	Nov.								1			7	4	2	
	Dec.											20	12	1	1
	Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**27**	**16**	**3**	**1**
2020	Jan.	2	29						4			15	7	2	5
	Feb.	24	195	2	9			1	10		1	19	22	1	15
	March	13	272	3	13		2	13	96			22	26	1	8
	April	7	146	2	10				8						
	May	9	112	2	11			2	35						
	June	11	100	3	6		3	12	16			1	1		
	July	19	39	3	13		1	11	21			7	1		
	Aug.	14	44	6	4		1	9	13			1	2		1
	Sept.	15	35		2			3	1			6			
	Oct.	29	62		1			3	1						
	Nov.	34	70		3	1	1			7					
	Dec.	31	66		2	2	1	2	4	3	1				
	Total	**208**	**1170**	**21**	**74**	**3**	**9**	**56**	**209**	**10**	**2**	**71**	**59**	**4**	**29**
2021	Jan.	51	78		4		2	5		3	2	9	3	2	3
	Feb.	28	67		8			2		1		8	3		1
	March	24	80		2		1	1				24	11		1
	April	16	45				1					19	12	1	2
	May	23	79		2	2	2	2	2	1		7	7		1
	June	9	51			2		1		1		1	1		
	July	3	15			3			1	1					
	Aug.	5	7				1		1	2		1			
	Sept.	7	16		1										
	Oct.	11	28		1	2				2					
	Nov.	2	27			1				2	2				
	Dec.	5	27			3	2			3					
	Total	**184**	**520**	**0**	**18**	**13**	**9**	**11**	**4**	**16**	**4**	**69**	**37**	**3**	**8**
2022	Jan.	13	19		3	5	2			3	2				

Short Biography of the author

Dr. Md. Ibrahim Khalil is working as a Scientific Officer in the Field Disease Investigation Laboratory, Barishal under the Department of Livestock Services (DLS), Bangladesh. He obtained his Doctor of Veterinary Medicine Degree in 2012 and MS in Animal and Poultry Nutrition in 2016 from Chattogram Veterinary and Animal Sciences University, CVASU, Bangladesh. In 2017, he joined in the Bangladesh Civil Service and worked as a field veterinarian in the Barishal, Bangladesh. After 3 years of field service, he enrolled in the 1st cohort of FETPV course in 2020, which is linked with the degree of MS in Applied Veterinary Epidemiology under the One Health Institute, CVASU.

Dr. Khalil long term goal is to establish veterinary epidemiology institution in Bangladesh under the Department of Livestock Services (DLS) to address One Health research and development on zoonotic and livestock diseases informatics, develop of systems for forecasting and forewarning of economically important livestock and zoonotic diseases, carry out the epidemiological surveillance of diseases/pathogens of lab animals and wildlife.

He started his One Health approach journey from the Rabies Action for Center Excellence (RACE) project of FAO-ECTAD. He conducted KAP study on Rabies with Cameron Pryor, FAO volunteer and DVM/MPH candidate 2021, Tufts University, USA, then collected the first rabid dog sample from the field level, eventually used to diagnose the rabies virus in Bangladesh central laboratory. Moreover, he completed advanced rabies diagnosis training in the WOAH rabies reference laboratory, Bengaluru, India. He is an executive member of One Health Young Voice in Bangladesh.

He is working as a technical group member of One Health Surveillance and Response for Controlling Anthrax (GHD) and developing the Standard Treatment Guidelines (STGs) for large animal projects (FAO-ECTAD) in Bangladesh. Furthermore, Antimicrobial Resistance (AMR) is his interested area to work. This FETPV thesis work is to assess the disease and antimicrobial use pattern. Recently, he is trying to develop regional AMR surveillance in the Field Disease Investigation Laboratory (FDIL), Barishal; and this is very first step in the FDIL, Barishal, which is a collaborative work assisted by several experts of home and abroad.

He is also working as a trainer of basic GIS mapping and participatory epidemiology. He is supporting in data mapping and data analysis of different projects of government and NGOs. He published different articles on peer reviewed journals on different zoonotic disease and One Health issues. Beside this thesis work, he is working with different research projects of home and abroad researchers including dengue outbreak, antimicrobial usage in poultry production and biosecurity in backyard poultry farming.

Now, he is a candidate for the degree of MS in Applied Veterinary Epidemiology under the One Health Institute, CVASU.