A UNIQUE COST-EFFECTIVE DISEASE SURVEILLANCE MODEL FOR SOUTHERN AFRICAN VILLAGE PIGS AND CHICKENS

Thesis submitted under the cotutelle agreement between James Cook University, Townsville, Australia and the University of Pretoria, Pretoria, South Africa

by

Vincent Simbizi

DVM, MSc

for the degree of Doctor of Philosophy

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STATEMENT OF ACCESS

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Name of candidate: Vincent SIMBIZI

Nature of assistance	Contribution	Names, Titles (if relevant) and Affiliations of Co-Contributors
Intellectual support	Study design and academic supervision	Prof. Bruce Gummow (Principal supervisor, JCU) Prof. Celia Abolnik (co-supervisor, UP) Prof. Gavin Ramsay (co-supervisor, CSU) Dr Rebone Moerane (co-supervisor, UP) Dr Chrisborn Mubamba (co-supervisor, Veterinary Services, Zambia)
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Name of candidate: Vincent SIMBIZI

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DECLARATION OF ETHICS

The research conducted under a cotutelle programme between the University of Pretoria and James Cook University and presented in this thesis was approved by the human and animal ethics committees of University of Pretoria with ethics approval numbers of GW20180835HS and V038-18 respectively. It was also approved by the research ethics committee from the Faculty of Veterinary Science, University of Pretoria (REC109-18). Authority to conduct the research in South Africa was granted by the Department of Agriculture, Land Reform and Rural Development under section 20 (reference number 12/11/1/1/8).

SUMMARY

Pig and chicken farming provide an important protein and revenue source for communities in developing countries. Despite these benefits, these two sectors in the Eastern Cape Province (ECP) of South Africa are still underdeveloped and poorly surveyed for pig and chicken diseases. The mechanisms for early detection of diseases remain a challenge, consequently, mortalities due to important infectious diseases are frequent. While the province faces a critical shortage of veterinary resources including limited budget, this study aims to examine ways by which animal disease surveillance in the ECP could be better targeted to enable more efficient use of existing veterinary resources.

Consequently, the overall objective of this study was to propose a system to promote early detection of pig and chicken diseases, based on social network and value chain analyses, which could be combined using ensemble modelling. Ensemble modelling is the process of running two or more related but different analytical models and then synthesizing the results into a single outcome. The work presented in this thesis was broken down into a hazard analysis component, farming and disease management component, risk analysis component and a proposal on a placement of surveillance units in the trade hubs identified by social network analysis. Each component had its own separate outcome. These components were thereafter combined to create an ensemble model for cost-effective surveillance of the smallholder pig and chicken farming sector in the ECP.

Within this context, a hazard analysis was a review of pig and chicken diseases in the province from 2000–2020. This review included relevant published papers identified by a computerized literature search from Web of Science; provincial animal health reports; the national database from the Department of Agriculture, Land Reform and Rural Development (DALRRD); animal health reports submitted by DALRRD to the World Organization for Animal Health (WOAH) via the World Animal Health Information Database (WAHID) interface and laboratory records. The review identified 174 publications of which 26 were relevant based on the selection criteria. Classical swine fever and Newcastle disease were the most reported diseases in pigs and chickens respectively, and they were consistently recorded in both the National database and

WOAH database. These diseases were therefore used as the primary hazards in the ensemble model. The retrieved literature on pig and chicken diseases was scarce and no longer up to date, providing decision makers with no current information on which disease to prioritize. The review identified zoonotic diseases that require further studies yet failed to find information on important neglected diseases like leptospirosis.

To establish how farmers dealt with chicken diseases, a sociological survey of chicken farmers and the remedies most used to prevent diseases in their flocks was conducted throughout the ECP between February 2019 and June 2019, alongside a serological survey to estimate the apparent seroprevalence of selected chicken diseases in the province (from August 2019 to March 2020). Most chicken farmers in the survey were females and pensioners (69 % and 66.1 % respectively) and had a primary school education (47.1 %). Traditional remedies were commonly used by farmers (47.15 %) and among the remedies, Aloe plant (*Aloe ferox* Mill.) or "ikhala" in local language (isiXhosa) was the most used product (28.23 %) to prevent and reduce mortalities among village chickens. The second group of remedies used by farmers was antibiotics with tetracyclines being the most used remedy under this category (17.42 %) followed by Sulpha products (12.01 %).

The conclusions drawn from this component were: i) the sector was dominated by pensioners with a low level of education; ii) village chickens could be a potential source of emerging diseases including virulent Newcastle disease virus (NDV) because of the lack of vaccination and biosecurity by farmers; iii) the use of antibiotics by untrained chicken farmers was a major public health concern as it could serve as a source of antimicrobial resistance (AMR); iv) the overall seroprevalence of Newcastle disease (ND), avian influenza (AI), avian infectious bronchitis (IB) and *Mycoplasma gallisepticum* (MG) in the province were 69.2 % (95 % CI 51.9 - 86.5%); 1.8 % (95 % CI 0.2 - 3.4%); 78.5 % (95 % CI 74.9 - 82%) and 55.8 % (95 % CI 41.3 - 70.3%) respectively with clustering found at the district level; v) chickens were exposed to the ND vaccine strains caused by spent hens from commercial operations that were being sold to rural farmers by traders and released into rural settings; vi) AI ELISA-positive samples were tested using HIs against the H5, H6 and H7-subtypes, but only H6-specific antibodies were detected (H6N2). Since these viruses can mutate and reassort among chickens, and they can infect humans (zoonosis), they require regular monitoring by the government and the poultry industry.

To understand the role of smallholders in the biosecurity and prevention of pig diseases a questionnaire survey of smallholder pig farmers was carried out at the same time as the chicken farmer's survey using ASF as a model. In parallel, a serological survey of pigs was conducted (from August 2019 to May 2020) to estimate the seroprevalence of ASF at provincial level. A total of 1000 pig sera were collected. Females represented 52% of pig farmers and reflected the cultural importance of pig farming in Xhosa culture. All the farmers interviewed had low biosecurity measures on their farms. The conclusions drawn from this component of the study were: i) the industry was dominated by female pensioners; ii) a low level of education, lack of training and reliance on the use of remedies to treat and prevent pig diseases for the majority of farmers were a key finding that could explain the poor implementation of biosecurity measures; iii) a poor knowledge of antibiotic use by farmers was likely to contribute to antimicrobial resistance (AMR) in these pigs; iv) smallholder farms were frequently involving free-ranging pigs, swill feeding and informal trading; practices known to contribute to the spread of ASF and other communicable pig diseases; v) our findings showed that smallholder pig farming could therefore be a source of high risk disease incursion and spread due to poor biosecurity measures; ; vi) the seroprevalence of ASF was found to be 0.01% (95% CI 0 - 0.015) with clustering found at the district level.

The risk assessment included a questionnaire survey targeting chicken farmers, which involved a chicken value chain analysis and an assessment of trading practices to identify biosecurity hotspots as well as an identification of barriers to market entry for rural chicken farmers. This survey took place from February 2019 to June 2019. Secondly, a study on the movement of live chickens and chicken products in the province using the Social Network Analysis (SNA) was carried out to identify trade hubs that could be targeted for disease surveillance based on their centrality within the network and their size and influence within their ego networks. This was done by conducting another survey targeting other actors identified by farmers in the first survey, from November 2020 to July 2021. The conclusions drawn from the risk assessment were: i) traders and their transport vehicles were identified as biosecurity hotspots that could be targeted for disease surveillance within the chain; ii) social network analysis identified three municipalities viz. Umzimvubu, King Sabata Dalindyebo (KSD) and Enoch Mgijima as trade hubs where interaction between chickens from rural settings and spent hens from commercial operations occurs and where resources can be focused; iii) the movement of spent hens from commercial operations that are transported over long distances and distributed in the rural areas and townships were a major risk for spread of chicken diseases; iv) the main barriers to market entry for chicken farmers included production constraints and current policy.

The second part of the risk assessment included an interview-based questionnaire survey targeting smallholder pig farmers and other participants involved in the smallholder pig value chain in the ECP which was conducted in two stages; from February to June 2019, as an initial survey targeting pig farmers, followed by a second survey from November 2020 to July 2021, based on information provided by pig farmers in the first survey. The second survey targeted abattoirs, meat traders, butcheries, supermarkets, and pig processors identified by the farmers. The objective of this survey was to analyse the smallholder pig value chain and movement of pigs and pig products using the SNA for informing targeted surveillance in the rural ECP, to better utilise the resources available and provide a cost-effective active surveillance system that promotes early detection of diseases, reduced mortalities, and increased production. The results showed that the sector was dominated by pigs and pig products from rural settings that could be traded among municipalities, without meat inspection, posing a risk to the spread and propagation of diseases. The conclusions drawn from this part of the risk assessment were: i) backyard pig producers act as biosecurity hotspots due to the low biosecurity measures on their farms as well as their trade practices; ii) three municipalities in the ECP namely Nelson Mandela Bay, King Sabata Dalindyebo and Enoch Mgijima were identified by SNA as trade hubs; iii) active surveillance of backyard pig producers in these hubs could result in more rapid detection of disease outbreaks and a quicker response using the same available capacity; iv) a risk-based surveillance system within veterinary services based on targeted surveillance will improve the reporting system and provide more efficient use of available resources.

The outcome of the project shows that a change in the current passive surveillance system, which encompasses 33 municipalities in the rural sector of ECP, to the placement of surveillance units in each trade hub would be more sensitive to early detection of disease, be more cost-effective and risk based. Each surveillance unit would be responsible for routine active surveillance within the biosecurity hotspots using the existing veterinary resources. Such surveillance units would also be responsible for risk communication between veterinary services, extension services and farmers in the hubs using the existing farmer's platforms or clubs. The resulting real-time exchange of information would improve disease reporting, risk communication and community engagement. The existing farmer's platforms should be used by the surveillance units and other stakeholders to train farmers in biosecurity and antimicrobial use thus reducing the risk of animal diseases emerging and spreading within and from the smallholder farming sector.

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LIST OF ABBREVIATIONS AND ACRONYMS

AIDS: Acquired Immune Deficiency Syndrome

AHT: Animal health technician

AMR: Antimicrobial resistance

AIB: Avian infectious bronchitis

AIL: Avian infectious laryngotracheitis

AI: Avian Influenza

AL: Avian leukosis

APMV-1: Avian paramyxovirus-1

ASF: African swine fever

CSF: Classical swine fever

CoAHW: Community animal health worker

CI: Confidence interval

DALRRD: Department of Agriculture, Land Reform and Rural Development

DRDAR: Department of Rural Development and Agrarian Reform

DD: Deputy Director

ECP: Eastern Cape Province

ELISA: Enzyme Linked Immuno Sorbent Assay

FAO: Food and Agriculture Organisation

FP: Fowl pox

GDP: Gross Domestic Product

HI: Haemagglutination Inhibition

HPAI: Highly pathogenic avian influenza

HIV: Human immune virus

IBD: Infectious Bursal Disease

KSD: King Sabata Dalindyebo

LCL: Lower Confidence Level

MG: *Mycoplasma gallisepticum*

NICD: National Institute of Communicable Diseases

ND: Newcastle Disease

NDV: Newcastle Disease Virus

NMB: Nelson Mandela Bay municipality

OIE: Office International des Epizooties

S/N: Sample to negative ratio

S/P: Sample-to-positive ratio

Se: Sensitivity

SNA: Social Network Analysis

SADC: Southern African Development Community

Sp: Specificity

State Vet: State veterinarian

UCL: Upper Confidence Levels

VPH: Veterinary Public Health

WAHID: World Animal Health Information Database

WAHIS: World Animal Health Information System

WOAH: World Organisation for Animal Health

ZAR: South African Rand

VET: Veterinarian or veterinary

CHAPTER 1

GENERAL INTRODUCTION

1.1 Justification

Historically, farming has been a cornerstone for human survival, which means humans are depended on the environmental resources for their everyday food security. Animal production, therefore, is first and foremost about providing a growing global human population with essential dietary protein from animals. A 70% increase in food production will be required by 2050 (FAO, 2009), in order to meet the nutritional needs of the world's postulated population increases to 9.8 billion (UN, 2017). The largest of this population growth is expected to be in Africa. Demand for and consumption of livestock products have steadily increased in Africa due to robust and sustained economic growth coupled with population growth, rising incomes, a growing middle class, and urbanisation, all driving a shift in dietary habits. The estimated average consumption of meat and milk is expected to increase to 26 kg and 64 kg, respectively, by 2050 (Baker et al., 2013). The bulk of the increased global demand will have to come from intensive pig and poultry systems and greater efficiency of production on pasture, as the potential for raising the numbers of grazing systems is limited (Scollan et al., 2010).

Eastern Cape Province (ECP), the second largest in South Africa, is home to 6,676,590 people (STATS, 2021) and this number is expected to increase. Since 1994, the challenges of tackling the pervasive poverty in South Africa have been prioritized. This has led to the enactment of various policies and initiatives, and pragmatic steps have been taken. Some projects have yielded dividends, but, data released by the Eastern Cape Socio Economic Consultative Council (ECSECC), indicates that Eastern Cape Province remained the poorest province, with 12.7% of its households classified as poor (ECSECC, 2017). Although agriculture is important in poverty alleviation, this industry only accounts for 1.9% of the provincial GDP (ECSECC, 2022).

Livestock farming in communal grazing areas of the ECP of South Africa is mostly subsistence and characterized by low inputs and outputs. In the communal areas of the ECP, livestock farming comprises fully integrated mixed units consisting of cattle, poultry (the term "poultry" used in this study simply refers to domestic chickens irrespective of the breeds), pigs, sheep, and goats. Farmers generate income from the sale of livestock and their by-products, thus contributing to farm household livelihood, poverty alleviation and food security (Mthi et al., 2017). Pig and poultry production systems have a particular importance in the ECP, because beside their contribution to food security, they are part of the traditional way of life of the Eastern Cape community. Based on data from Statistics SA, ECP has a largest number of agricultural households engaged in pig and poultry farming (STATS, 2016).

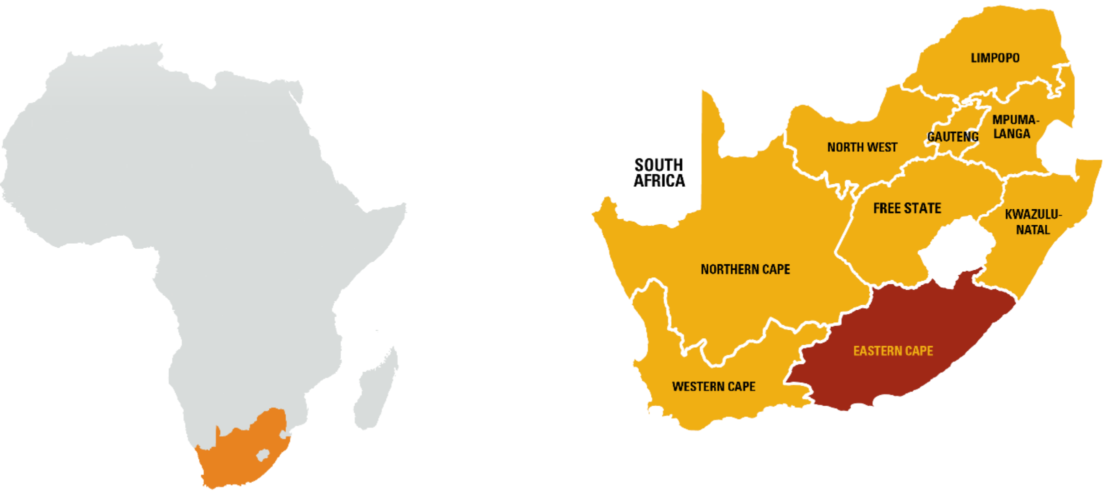

Figure 1: Map of Africa showing South Africa and Eastern Cape Province of South Africa

1.2 Overview of pig and poultry industry in South Africa

1.2.1 Pig industry

South Africa has three distinct sectors of pig farming. The first sector comprises commercial farms that maintain closed herds with high biosecurity and feed commercial pig rations. Their pigs are slaughtered at commercial abattoirs (Mokoele et al., 2015).

The second sector comprises small and semi-commercial units, which have low biosecurity with frequent movements of stock between farms, including auctions. Rations vary greatly but can include cooked and illegally fed swill. These farms usually supply local markets and few pigs are slaughtered at abattoirs (Mokoele et al., 2015).

The third sector includes partially to fully free-range pigs in rural areas. Pigs roam freely and swill is the main feed. These pigs are occasionally confined to protect crops and are slaughtered informally for special events and contribute to food security for those with a low socio-economic status (Mokoele et al., 2015).

There are approximately 4 000 commercial pig producers and 19 stud breeders in South Africa. Pig numbers were estimated at 1.389 million for the year 2019 with Limpopo and North West provinces, the largest producers, accounting for 24% and 21% respectively followed by Western Cape and Gauteng, with a share of 11% each (DALRRD, 2020). From 2009 to 2019, South Africa consumed more pork meat than they produced, which made the country self-insufficient in pork production except during the year 2013-2014, where the production slightly exceeded the consumption. This caused the country to import pork to meet local demand (DALRRD, 2020). Even though South Africa is a net importer of pork, there are other pork products that are exported. South Africa exported approximately 92 426 tons of pork from 2010 to 2019, yielding an export value of approximately R 2.4 billion over the same period. South African pork exports represent approximately 4% of local production. South African pork is mainly exported to the Southern African Development Community (SADC) countries, which constitutes 93% of the total pork exports (DALRRD, 2020).

This study focuses on the last two sectors because of the roles played in food security for rural communities of ECP where large commercial farms are rare.

1.2.2. Poultry industry

The poultry industry in South Africa is subdivided into four sub-categories: the day-old chick supply industry, the egg industry, the broiler industry, the subsistence and small commercial farmers (SAPA, 2021). The present study focuses on subsistence and small commercial farmers (smallholder chicken farmers) but because of the role played by larger commercial poultry producers in supplying the smallholder chicken farming with some inputs (e.g., day-old chicks), a brief description of commercial poultry industry is given.

South Africa is the largest commercial poultry-producing country on the African continent, and its industry is dominated by a few fully integrated large commercial producers, and a high volume of small-scale producers, either as contract growers or individual producers supplying the informal market (Nkukwana, 2018). The industry is the largest segment of the country's agricultural sector, contributing more than 16% of its share of gross domestic product. In 2021, approximately 16.6 % of the total agricultural gross value and 39.9 % of animal product gross value was derived from poultry production (SAPA, 2021). The industry provides employment, directly and indirectly, for about 110 000 people throughout its value chain and related industries

(SAPA, 2021). Comparatively, on a global context, the South African poultry industry struggles to remain competitive. Profit margins are hampered by feed costs, often making up 75% of total production costs (Nkukwana, 2018). Due to the high demand, the country has become the net importer of dark meat, which is sold to South Africa at prices below the cost of production from Brazil, the United States and the European Union (EU) (Louw et al., 2017; Nkukwana, 2018). These countries produce a large quantity of cereal grains and oilseeds for poultry farming and are subsidized, whereas South Africa has an insufficient supply of locally grown inputs for feed manufacturing (Nkukwana, 2018). This has caused South Africa to import approximatively 90% of its soybean meal requirements (Davids, 2013) making the production cost more expensive. Other factors that have a negative impact on the cost of production include recent drought effects on crop production and the consistent poor performance of the Rand against other currencies at the international markets.

1.2.3 Pig and poultry sector in the rural Eastern Cape Province as an alternative solution to poverty and food insecurity.

The rural sector of ECP has the potential to grow, given the fact that the commercial pig and poultry sectors in the province are small and only contribute 6% and 6.5 % of total production countrywide respectively (SAPA, 2017; DAFF, 2018). The ECP is regarded as the 'homeland' of livestock and has a comparative advantage over other provinces due to the fact that it has the highest number (31%) of agricultural households engaged in poultry farming (an average of 1–10 chickens per household) compared to other provinces in South Africa (STATS, 2016). Similarly, family ownership in the Eastern Cape accounts for about 50% of pig numbers in the small-scale and communal sectors in South Africa (Meissner et al., 2013). This comparative advantage is yet to be fully exploited to address the poverty and food security threat affecting the province.

Small livestock, such as pigs and poultry are largely kept by land scarce, resource-poor households for commercial and consumption purposes because of their low initial investment and operational costs and because of their major roles in the social, cultural and economic environment in the Eastern Cape Province. Various researchers have confirmed that chickens in the rural settings have a potential to unlock farmers from poverty in several parts of the world including South Africa (Gueye, 2000; Dolberg, 2003; Sonaiya, 2007; Alders and Pym, 2009; SAPA, 2020) and contribute significantly to the improvement of the quality of life by providing scarce animal protein in the form of meat and eggs, which can be sold to meet essential family needs (Gueye, 2000). Village chickens are active in pest control, provide manure and are essential for many traditional ceremonies. They are generally owned and managed by women and children and are often essential elements of female headed households (Gueye, 2000). Similarly, pig farming serves as a source of food, income, security and plays an important cultural role for many resource-poor farmers (Madzimure et al., 2014; Penrith et al., 2019).

While the livestock sector is characterized by production systems ranging from village subsistence farms to large commercial units in many developing countries (Brioudes, 2016), this sector in the ECP is predominantly smallholder-based with a high proportion of the population living in rural settings and raising livestock with little to no biosecurity (Penrith et al., 2019). Improved biosecurity at the different steps of the livestock market chain, from production to consumption, is needed. The health certification by veterinary services and food safety standards must be improved to prevent the introduction of animal pathogens and limit their potential impact on the livestock production and spread in the province and in the region (Brioudes, 2016).

1.2.4 Infectious diseases in pig and poultry sector of rural Eastern Cape Province

As in many Sub-Saharan African countries, infectious diseases constitute a major obstacle to the development and expansion of pig and poultry sectors in the rural ECP. Commonly reported diseases in domestic poultry over the past twenty years include Newcastle disease, avian influenza, avian infectious bronchitis and mycoplasmosis (DAFF, 2020). The economic impact of these diseases still needs to be determined.

Newcastle disease (ND) is caused by virulent strains of avian paramyxovirus type 1 (APMV-1) of the genus *Avulavirus* belonging to the family *Paramyxoviridae* (WOAH, 2018c). Twenty-one serotypes of avian paramyxoviruses have been recognised: APMV-1 to APMV-21 (WOAH, 2021). APMV-1 is split into two classes: Class I consists of APMV-1 viruses commonly isolated from wild birds, whereas the Class II viruses are the most commonly reported and are associated with disease in poultry (Diel et al., 2012). The disease has a worldwide distribution and affects more than 250 bird species. It is endemic in many parts of the world and has been known to cause epizootic outbreaks in domestic poultry on six of the seven continents (Miller et al., 2010). Infected birds shed Newcastle disease virus in oropharyngeal secretions and faecal matter (Kinde et al., 2005). Clinical symptoms and the severity of ND depend on a range of factors including host species, age, immune status and viral characteristics, although respiratory and neurological symptoms are typical (Alexander, 2000). Avian paramyxovirus infections have usually been diagnosed by serology or virus isolation. In common with ND, antibodies to APMVs may be detected by HI tests using the relevant antigens and controls. Avian paramyxoviruses can be isolated from tracheal or faecal swabs or tissue samples from infected birds by inoculation of eight to ten-day-old embryonating chicken eggs via the allantoic cavity. Confirmation of the virus as belonging to the APMV serotype can be performed by HI tests with specific antiserum (Alexander, 2000).

Avian influenza (AI) is a highly contagious and zoonotic disease of domestic and wild avian species. AI viruses are classified in the family *Orthomyxoviridae*, genus Influenza virus A or type A. There are at least 16 known serological distinct subtypes based on the surface hemagglutinins and 9 based on neuraminidases that infect birds. Based on the severity of the illness caused, avian influenza viruses are divided into two distinct phenotypes: the highly pathogenic avian influenza (HPAI) and the low pathogenic avian influenza virus (LPAI) (Taunde et al., 2017). The World Organization for Animal Health uses the designation of notifiable AI (HP notifiable AI: HPNAI) and LP notifiable AI (LPNAI) for international animal health regulatory purposes (WOAH, 2006). HPNAI encompasses only H5 and H7 LPAI, subtypes that have been shown to convert from LP to HP viruses naturally in poultry (Swayne et al., 2013). Reassortment events among influenza viruses occur naturally and may lead to the development of new and different subtypes which often ignite the possibility of an influenza outbreak (Antigua et al., 2019).

The HPAI is expressed as a severe, highly fatal systemic disease that affects most organ systems with morbidity and mortality approaching 100% (Swayne and Suarez, 2000). Most infections by LPAI viruses in wild birds produce no clinical signs (Swayne et al., 2013). In domestic poultry, they cause a much milder disease consisting primarily of mild respiratory disease, depression and egg production problems in laying birds (Alexander, 2008) but may, in certain circumstances, produce a spectrum of clinical signs, the severity of which may approach that of HPAI, particularly if exacerbating infections and/or adverse environmental conditions are present (WOAH, 2018b). The AI virus is shed from the nares, mouth, conjunctiva, and cloaca of infected birds as well as from the epidermis (feathers, feather follicles and glands) in the case of HPAI (Perkins and Swayne, 2001) resulting in environmental contamination. The transmission occurs by direct contact between infected and susceptible birds or indirect contact through aerosol droplets or exposure to virus-contaminated fomites. A definitive diagnosis of AI is established by direct detection of AI viral proteins or genes in specimens or isolation and identification of AI virus. A presumptive diagnosis can be made by detecting antibodies to AI virus (Swayne et al., 2013).

Mycoplasma gallisepticum (MG) infections are commonly known as chronic respiratory disease (CRD) of chickens and infectious sinusitis of turkey and they are regarded as the most pathogenic and economically significant mycoplasmal pathogen of poultry. The disease in chickens is characterized by respiratory rales, coughing, sneezing, ocular and nasal discharge, and decrease in feed consumption and egg production (Nascimento et al., 2005). Severe airsacculitis is often accompanied by infection with other respiratory pathogens, such as Newcastle disease virus, infectious bronchitis virus, and *Escherichia coli* (Nunoya et al., 1997; Raviv and Ley, 2013). It is transmitted horizontally by direct or indirect contact of susceptible birds with clinical or subclinical infected birds through aerosols or droplets (Bradbury and Levisohn, 1996) or vertically in eggs laid by naturally infected hens (Glisson and Kleven, 1985). Diagnosis includes isolation and identification of causative agent as well as serology for flock monitoring and to aid in diagnosis when infection is suspected (Raviv and Ley, 2013).

Infectious bronchitis is an acute and highly contagious gammacoronavirus of poultry affecting the respiratory and urogenital tract of chickens (Jackwood and de Wit, 2013). IBV is a listed disease according to the World Organization for Animal Health (Knoetze et al., 2014) and can result in many economic losses in the poultry industry worldwide (Erfanmanesh et al., 2020). The disease has a worldwide distribution. The severity of the clinical signs and impact is influenced by the IBV strain(s) involved and environmental circumstances such as climate, dust, ammonia, density and cold stress. The age and type of bird, its immune status, and presence of secondary or co-infections are also relevant factors (Jackwood and de Wit, 2013). The transmission may be by either inhalation or ingestion of infectious virus particles by direct contact between infected and susceptible birds; by indirect contact through aerosol droplets or faeces; and by exposure to virus-contaminated fomites. Clinical signs and lesions include respiratory symptoms, effects on egg production and egg shell quality and kidney pathology (Jackwood and de Wit, 2013). Mortality due to IBV infection alone is usually very low, but can be significant following secondary infections with bacteria such as *Escherichia coli* (de Wit and Cook, 2019). Diagnosis is based on the clinical history, lesions, sero-conversion, and IBV antigen detection by a number of antibody-based antigen capture assays, virus isolation, and detection of IBV RNA (WOAH, 2018a).

Classical swine fever (CSF) was the most reported pig disease in the ECP between 2000 and 2020 (DAFF, 2020). This disease also known as hog cholera, is a contagious viral disease of domestic and wild swine, caused by a virus of the genus *Pestivirus* which is closely related to viruses that cause bovine viral diarrhoea in cattle. Symptoms include fever, huddling of sick animals, loss of appetite, dullness, weakness, conjunctivitis, constipation followed by diarrhoea, and an unsteady gait. A few days after the onset of clinical signs, the ears, abdomen and inner thighs may show a purple discoloration. The most common method of transmission is through direct contact between healthy swine and those infected with CSF virus. CSF virus can survive in pork and processed pork products for months when meat is refrigerated and for years when it is frozen. Pigs can become infected by eating CSF-infected pork or products. Applying strict and rigorous sanitary prophylaxis, and hygiene measures protecting domestic pigs from contact with wild boar are the most effective measures to prevent the disease (WOAH, 2019). Classical swine fever has been eradicated in the ECP by a massive stamping-out campaign with nearly half a million pigs culled (Akol and Lubisi, 2010).

The control of these infectious diseases demands strategic planning aimed at targeting disease control measures in this area where they will have the most impact relative to the cost of implementing the control (cost effective). Sustained control of these diseases can be achieved by reducing the risks of disease transmission, in addition to quick disease detection, containment and response (FAO, 2011). To reduce risks, an understanding of the risks and the factors that determine them is required (risk analysis). Detailed knowledge about pig and poultry population and behaviour of the people involved in all stages of livestock production and market is an essential component of risk analysis and this knowledge can be developed and enhanced through value chain analysis (FAO, 2011).

South Africa has numerous world-standard veterinary diagnostic laboratories that are capable of screening for pig and poultry diseases, but the provincial authority lacks the financial resources to perform routine surveillance. Consequently, disease surveillance in communal areas is not regularly done and the risk of introducing new transboundary animal diseases and the risk of delayed detection or lack of detection, are increased.

It is therefore important for the province to undertake a new approach to achieve effective disease control. This will allow South Africa, as a member of the World Organization for Animal Health, to be able to declare confidently any suspected or present disease in the country. Consequently, the ECP will meet international requirements for export of live animals and animal products. In addition to giving the Eastern Cape Province the opportunity to access international markets, effective animal disease surveillance would create more benefits for rural farmers by enabling early detection of disease outbreaks, reducing mortalities and increased production.

1.3 Problem statement and hypothesis

1.3.1 Problem

There is little epidemiologic and empirical information on infectious diseases in smallholder pig and poultry sector and related biosecurity. Similarly, little information exists on the farmers' demographics and pig and poultry value chains in the rural settings of ECP and the way farmers deal with infectious diseases. There is no active surveillance of pig and poultry diseases in the rural ECP by veterinary services and poor passive surveillance due to poor communication structures. Finally, veterinary services in the ECP face a serious challenge of limited resources and capacity.

1.3.2 Hypothesis

Updating the knowledge of pig and poultry diseases and studying the movement of pig and poultry along the value chains in relation to the propagation of infectious diseases in the Eastern Cape Province, would facilitate the establishment of a risk-based surveillance and improve reporting system through the effective usage of existing resources.

1.4 Objectives of the research

The overall objective of the project was to propose a more effective system for early detection of pig and chicken diseases of economic importance, using an ensemble model that combines social networks and value chains approaches within the rural sector of Eastern Cape Province of South Africa. Ensemble modelling is the process of running two or more related but different analytical models and then synthesizing the results into a single outcome (Brioudes and Gummow, 2017).

Specific objectives for the project were:

1.4.1 To review pig and poultry disease reported and published in the province from 2000-2020 through a computerized literature search from Web of Science and other relevant databases including the national database, WOAH and other animal health reports from the province. This was done with a view of determining a knowledge gap on the current disease situation of pig and poultry diseases in the province.

1.4.2 To estimate the apparent seroprevalence of selected chicken diseases in the Eastern Cape Province of South Africa (serological survey) and to study the demographics of poultry farmers and the remedies most used to prevent diseases in their flocks through a questionnaire survey.

1.4.3 To describe the demographics and practices of smallholder pig farmers and understand their role in biosecurity and prevention of pig diseases using ASF as a model; and to conduct a serological survey of pigs to estimate the seroprevalence of ASF at provincial level.

1.4.4 To conduct a survey involving the rural chicken value chain analysis and an assessment of trading practices to identify biosecurity hotspots along the chain and barriers to market entry for rural farmers, and to use a social network analysis of chicken movements in the province to identify trade hubs and nodes that could be targeted for disease surveillance.

1.4.5 To conduct a survey involving the pig value chain analysis and an assessment of trading practices to identify biosecurity hotspots along the chain, and to use a social network analysis of pig movement in the province to identify trade hubs that could be targeted for disease surveillance.

1.4.6 To propose a novel approach for a cost-effective disease surveillance in pigs and chickens from rural ECP, and an improved reporting system within veterinary services based on targeted surveillance that engenders more efficient use of available resources.

1.5 Scope of the thesis

The chapters of this thesis cover the studies conducted, which were approached systematically and aligned to the ensemble model. Chapter 2 is a review of pig and poultry diseases in the Eastern Cape Province of South Africa, 2000-2020. Chapter 3 is a study of rural chicken farmers, diseases and remedies in the Eastern Cape Province of South Africa. Chapter 4 investigates the role of smallholder pig farmers in the biosecurity of pig diseases in the Eastern Cape Province of South Africa using ASF as a model. Chapter 5 is a study describing how to use value chain and trade networks in the Eastern Cape Province of South Africa, as a basis for targeted rural chicken surveillance. Chapter 6 is a study on rationalizing resources through targeted active surveillance of smallholder pig farmers in the Eastern Cape Province of South Africa. Lastly, a general discussion, conclusion and recommendations are presented in Chapter 7.

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CHAPTER 2

A REVIEW OF PIG AND POULTRY DISEASES IN THE EASTERN CAPE PROVINCE OF SOUTH AFRICA, 2000-2020

Publication

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ABSTRACT

The informal poultry and pig sector in the Eastern Cape Province of South Africa is of significant socio-economic importance as it sustains livelihoods and ensures food security; yet little is known about the distribution and prevalence of infectious and zoonotic diseases in this region. This paper reviews data published for pig and poultry diseases in the province during the last 20 years (from 2000 to 2020). The review included relevant published papers identified by a computerized literature search from Web of Science; provincial animal health reports; the national database from the Department of Agriculture, Land Reform and Rural Development (DALRRD); animal health reports submitted by DALRRD to the World Organisation for Animal Health (WOAH) via the World Animal Health Information Database (WAHID) interface and laboratory records. A publication was considered eligible if it included qualitative or quantitative information on any disease affecting pigs and poultry including zoonosis. The search retrieved 174 publications of which 26 were relevant. The review found that Newcastle disease, coccidiosis and fowl pox were the most reported avian diseases in the national database whereas avian infectious bronchitis, Newcastle disease and highly pathogenic avian influenza were the most reported diseases in the WOAH database. Classical swine fever was the most reported pig disease in both databases. The retrieved literature on pig and poultry diseases was scarce and no longer up to date providing decision makers with little information. The review identified important zoonotic diseases that require further studies yet failed to find information on important neglected diseases like leptospirosis.

Keywords*:* Pig; poultry; diseases; zoonotic; Eastern Cape Province; review.

2.1 Introduction

Transboundary animal diseases are highly contagious epidemic diseases that can spread extremely rapidly, irrespective of national borders. They cause mortality and morbidity in animals, thereby having serious socio-economic and sometimes public health consequences (FAO, 2020). The Eastern Cape Province is the second largest province in South Africa after Northern Cape (Figure 1). It is divided into two metropolitan municipalities and six district municipalities. The district municipalities are in turn divided into 27 local municipalities. The human population is estimated to be 6,734,001 (STATS, 2020) with the density of 39/km.^{2} The main industries include agriculture and mining (primary sector) which contribute 2% to the provincial GDP; manufacturing, electricity and construction (secondary sector) contributing 18.5% to the GDP; trade, transport, finance, personal services and government services (tertiary sector) contributing 79.5% to the GDP (ECSECC, 2018). Overall the province only contributes 8% to the national GDP (STATS, 2018). Eastern Cape Province is economically the poorest province in South Africa where subsistence agriculture predominates in the former homelands. Livestock plays a major role in the social, cultural, and economic environment in the province. Eastern Cape Province is among the lowest pork and poultry producing provinces with 6% and 6.5% of total production countrywide respectively (SAPA, 2017; DAFF, 2018). These production statistics are mainly commercial and don’t include backyard chickens (indigenous chickens) and free roaming pigs owned by many households in the province. The informal pig and poultry sector in the Eastern Cape Province is estimated to have 3,841,174 birds and 536,108 pigs (STATS, 2016). Apart from being a source of income for many households, pigs and poultry constitute a cheap source of protein for rural communities and ensures food security. However, little has been published on what diseases are present in these animals within the province. Due to financial constraints, animal disease detection in the province is mainly dependent on passive surveillance in village communities (A Fisher 2018, personal communication). This constitutes a major challenge since some diseases are being underreported or are not reported. Also, the province doesn’t have animal health information systems which could help in the collection and analysis of animal health data. Such animal health information is recognised as necessary for the setting of animal health priorities (Morris, 1991). Therefore, a systematic review of peer-reviewed articles, animal health reports and laboratory records compiling information on pig and poultry diseases in the province is presented with the view of identifying diseases of pigs and poultry kept within these rural communities. This will help decision makers to prioritise resources for animal disease surveillance and control in these communities.

Figure 2 Map of Eastern Cape Province with its municipalities

2.2 Methods

A review was carried out on what has been published on diseases of pigs and poultry in the Eastern Cape Province over the last 20 years (2000-2020). The review included relevant published papers identified by a computerized literature search of all databases (WOS, BCI, CABI, CCC, DRCI, DIIDW, FSTA, KJD, MEDLINE, RSCI, SciELO and ZOOREC) from Web of Science (Appendix 1), which is the global standard for finding and connecting scholarly content across multiple disciplines around the world; monthly reports on the animal health situation submitted by the Directorate of Veterinary Services in the province to the Department of Agriculture, Land Reform and Rural Development (DALRRD); the national database from DALRRD; official animal health reports submitted by DALRRD to the World Organisation for Animal Health (WOAH) and laboratory records from three provincial laboratories (Grahamstown, Middleburg and Queenstown).

2.2.1 Search strategy

2.2.1.1 All databases from Web of Science

All databases mentioned above were searched for published articles on pig diseases in the province from 2000 to 2020 using the following key words: Pigs OR Pig OR Swine OR Porcine (Search 1); Diseases (Search 2) and “Eastern Cape” OR (east* AND cape*) (Search 3).

Search 1; Search 2 and Search 3 were combined and all the published papers relevant to pig diseases in the Eastern Cape Province were selected.

The same search strategy was used for poultry and all databases were searched for published articles on poultry diseases in the province from 2000 to 2020 using the following key words: Chickens OR Chicken OR Poultry (Search 1); Diseases (Search 2) and “Eastern Cape” OR (east* AND cape*) (Search 3).

2.2.1.2 National database from DALRRD

The national database from DALRRD comprises all the disease reports from each province in South Africa. Each province consolidates different disease reports from the state veterinarians on a monthly basis. The Animal Diseases Act (35 of 1984) requires that all occurrences of controlled and notifiable diseases be reported to the national directorate. For other diseases and vaccinations, the national directorate requests provinces to include them in monthly reports for WOAH reporting purposes and to serve as indication of the presence and prevalence of these diseases. Some diseases that are not controlled can still have trade implications (DAFF, 2016). The final report from each province is then submitted to the epidemiology section of DALRRD which in turn, compiles and updates its national database. All disease reports from Eastern Cape Province were reviewed from 1999 to 2019. The national database comprises diseases that were reported from 1993 to 2019.

2.2.1.3 WAHID interface

All official animal health reports submitted by DALRRD to the World Organisation for Animal Health (WOAH) were reviewed via the World Animal Health Information Database (WAHID) interface (WOAH, 2020b) from 2005 to 2020.

2.2.1.4 Laboratory records at three provincial laboratories

Laboratory records were used to select pig and poultry diseases that were diagnosed at each of the three provincial laboratories in the province (Queenstown, Middleburg and Grahamstown).

2.2.2 Eligibility criteria

2.2.2.1 Inclusion criteria

A publication was considered eligible for this review if it included qualitative or quantitative information on any disease (bacterial, viral, parasitic and fungal) affecting pigs or poultry in the Eastern Cape Province. To have a wide range of reported diseases in the province, diseases affecting pigs or poultry from commercial farms were also included. Diseases affecting “poultry” other than chickens were also included. Finally, zoonotic diseases were also included in this review.

2.2.2.2 Exclusion criteria

Duplicate articles were excluded. Different references from the same study were counted as one reference irrespective of the format in which they were published (article, proceedings, workshop etc.). The inclusion and exclusion criteria were applied to the title and abstract of all retrieved references.

2.2.3 Data collection process

The data collection process was undertaken in two steps. First, basic information was collected from all retrieved articles to assess which diseases have been reported in the province. For this basic analysis, the following information was systematically recorded: the publication date, the district, the species, the disease, the type of causative agent (bacteria, virus, parasite, alga, toxins, tumour, fungi etc.), whether or not the reference focus was of a zoonotic disease, and the type of study (case report, case series, review or survey). In a second step, considering that the objective of this review was to obtain a better understanding of the current pig and poultry disease situation in the Eastern Cape Province, only documents published or written in the last 20 years were selected to focus on the most recent information. A more detailed analysis of the key findings from these references was then performed. The number of reported outbreaks for each disease was used to determine which disease was more frequently reported than others.

2.3 Results

2.3.1 Selected references and characteristics

The search strategy retrieved 174 publications of which 26 were relevant based on the inclusion and exclusion criteria (**Table 2** and **Table 3**). Eighteen references were surveys (69.2%), four were case reports (15.4%), one was a conference paper (3.8%) and three were general papers describing a particular disease nationally with little data provided for Eastern Cape Province (11.5%). The majority of references provided data on diseases for pigs (84.6%) whereas references for poultry represented 15.4%. A paper on both chicken and pig disease was represented by three references (11.5%). Seventy seven percent of the references referred to zoonotic diseases. The following zoonotic diseases (or agents) were found in this review: Hepatitis E virus; *Enterococcus*, *Salmonella*, *E. coli*, cysticercosis, chlamyodiosis, campylobacteriosis, norovirus, avian influenza, Newcastle and nocardiosis (Appendix 2).

Table 1: Pig diseases identified in the ECP between 2000 and 2020 from all databases from Web of Science

Disease	District	Year	Reference
Campylobacteriosis*	OR Tambo	2020	(Ngobese et al., 2020)
Campylobacteriosis*	Chris Hani and Amathole	2020	(Igwaran and Okoh, 2020)
Classical swine fever	Eastern Cape**	2010	(Akol and Lubisi, 2010)
E. coli	Amathole	2016	(Iwu et al., 2016b)
E. coli	Amathole	2017	(Iwu et al., 2017)
Enterococcus	Amathole	2015	(Iweriebor et al., 2015)
Hepatitis E virus	Chris Hani and Amathole	2017	(Adelabu et al., 2017)
Norovirus	Amathole and OR Tambo	2017	(Taku et al., 2017)
Porcine circovirus type 2	Chris Hani Amathole and OR Tambo	2017	(Afolabi et al., 2017)
Porcine circovirus type 2	Chris Hani Amathole and OR Tambo	2019	(Afolabi et al., 2019)
Salmonella	Amathole	2016	(Iwu et al., 2016a)
Salmonella	_	2017	(Mathole et al., 2017)
*Salmonella**	OR Tambo	2019	(Mthembu et al., 2019)
Swine Fever	Eastern Cape**	2013	(Penrith, 2013)
Taenia solium	OR Tambo and Alfred Nzo	2008	(Krecek et al., 2008)
Taenia solium	OR Tambo and Alfred Nzo	2012	(Krecek et al., 2012)
Taenia solium	OR Tambo and Alfred Nzo	2013	(Krecek et al., 2013a)
Taenia solium	OR Tambo and Alfred Nzo	2013	(Krecek et al., 2013b)
Taenia solium	Eastern Cape**	2016	(Syakalime et al., 2016)
Taenia solium	OR Tambo and Alfred Nzo	2019	(Sithole et al., 2019b)

Taenia solium	OR Tambo and Alfred Nzo	2020	(Sithole et al., 2020)
Taenia solium	OR Tambo and Alfred Nzo	2019	(Sithole et al., 2019a)

*: Disease found in both pigs and poultry; ** The article referred to the whole province

Table 2: Poultry diseases identified in the ECP between 2000 and 2020 from all databases from Web of Science

Disease	Species	District	Year	Reference
Avian influenza	Ostriches	Sarah Baartman	2005	(Manvell et al., 2005)
Avian Influenza (H5N2)	Ostriches	Eastern Cape	2009	(Abolnik et al., 2009)
Avian Influenza (H5N8)	Wild birds and poultry	South Africa including Eastern Cape	2019	(Abolnik, 2019)
Salmonella	Swine and chickens	OR Tambo	2019	(Mthembu et al., 2019)

* Disease found in both pigs and poultry

2.3.2 Selected diseases from national database, WOAH and laboratories records

A total of 14 diseases (10 poultry diseases and 4 pig diseases) were retrieved from the national database (**Table 4**). Poultry diseases were subdivided into three categories: viral, bacterial and protozoal diseases (**Figure 3**). Viral diseases were most often reported (135 reported outbreaks representing 73% of all the outbreaks) followed by protozoal diseases (37 outbreaks; 20%) and bacterial diseases (13 outbreaks; 7%) (**Figure 3**). Among viral diseases, Newcastle disease (ND) was the most reported disease in the Eastern Cape Province with 103 outbreaks in the past 20 years followed by fowl pox (FP) with 18 outbreaks; avian leukosis (AL) with 9 outbreaks; Gumboro and avian infectious bronchitis (AIB) with 2 outbreaks each and avian infectious laryngotracheitis (AIL) with one outbreak (**Figure 4**).

Table 3: List of pig and poultry diseases found in the ECP in the national database (DALRRD) from 1999 to 2019

Disease	Species	Number of reported outbreaks*
Mycoplasma gallisepticum	Avian	10
Newcastle disease	Avian	103
Gumboro	Avian	2
Fowl cholera	Avian	2
Avian infectious bronchitis	Avian	2
Fowl pox	Avian	18
Coccidiosis	Avian	37
Salmonella enteritidis	Avian	1
Avian infectious laryngotracheitis	Avian	1
Avian leukosis	Avian	9
Classical swine fever	Swine	99
Swine erysipelas	Swine	2
Cysticercosis	Swine	4
Coccidiosis	Swine	1

*: Source of data is given in the Appendix 3

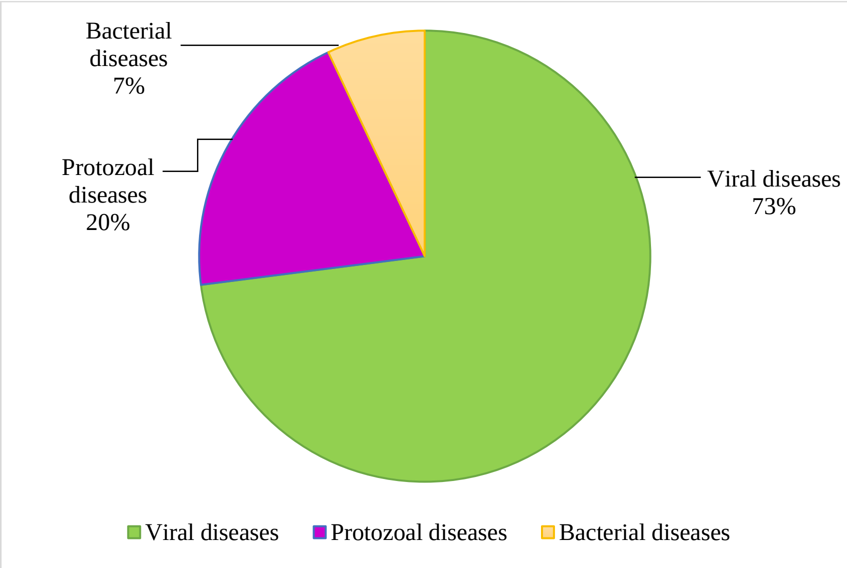

Figure 3: Frequency of reported poultry diseases per category

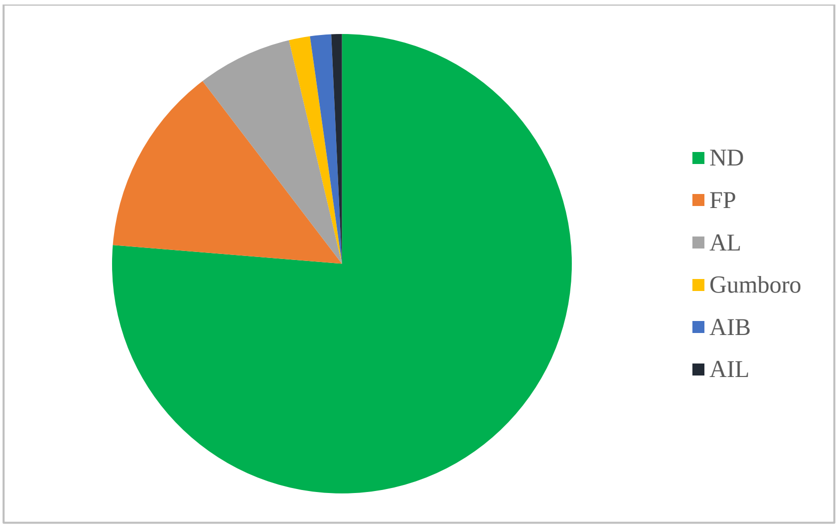

Figure 4: Frequency of poultry viral diseases reported in the ECP from 1999 to 2019 in the national database (DALRRD): ND: 103 outbreaks; FP: 18 outbreaks; AL: 9 outbreaks; Gumboro and AIB: 2 outbreaks; AIL: 1 outbreak.

For pig diseases, classical swine fever (CSF) had the most reported outbreaks among pig diseases (99 outbreaks representing 93.4%), followed by cysticercosis (4 outbreaks representing 3.8%), swine erysipelas (2 outbreaks representing 1.9%) and coccidiosis (one outbreak representing 0.9%) (**Figure 5**).

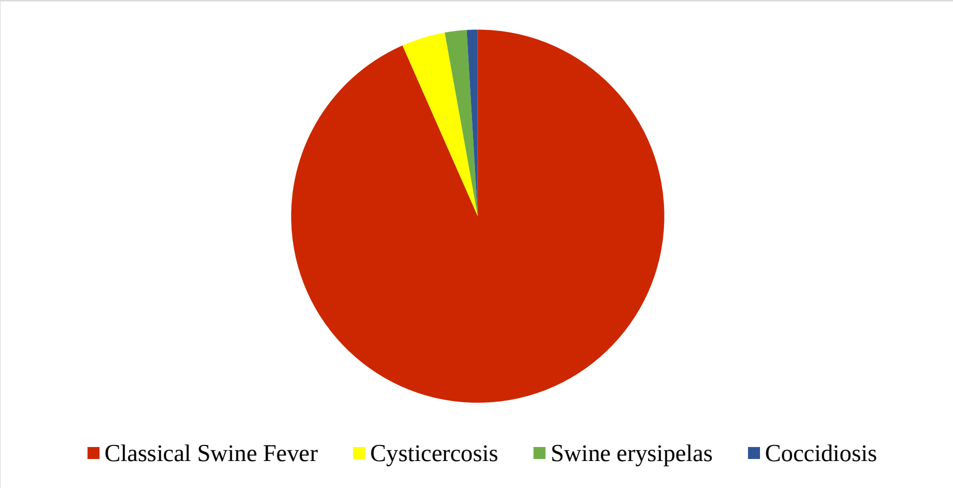

Figure 5: Frequency of reported pig diseases in the national database (DALRRD) from 1999 to 2019: classical swine fever (99 outbreaks); cysticercosis (4 outbreaks); swine erysipelas (2 outbreaks) and coccidiosis (1 outbreak).

A total number of nine diseases were retrieved from the WOAH database (**Table 4**). The most reported poultry diseases from 2005 to 2020 were avian infectious bronchitis (AIB) and Newcastle disease (ND) (reported 7 times) (**Table 4**) followed by highly pathogenic avian influenza (HPAI) (reported 6 times). For pig diseases, the most reported disease was classical swine fever (CSF) (**Table 4**). Additional information on diseases prevalent in the province was obtained from the provincial laboratories despite the fact that these laboratories did not have much information on pigs and poultry diseases over the past twenty years (Appendix 4, Appendix 5 and Appendix 6).

Table 4: List of pig and poultry diseases found in the WOAH database (WAHID interface) from 2005 to 2020 (WOAH, 2020a)

Disease	Species	Number of reported outbreaks*
Fowl pox	Avian	1
Avian infectious bronchitis	Avian	7
Newcastle disease	Avian	7
LPAI (poultry)	Avian	5
HPAI	Avian	6
Gumboro	Avian	2
Mycoplasmosis	Avian	1

Fowl cholera	Avian	2
Classical swine fever	Swine	3
African swine fever	Swine	1

* The reported outbreaks are given in detail in the Appendix 7

2.4 Discussion

2.4.1 Data limitations

Despite the economic importance of the pig and poultry sectors in the Eastern Cape Province, this study found very little published information on pig and poultry diseases in the province over the past 20 years, which made it difficult to conduct a meta-analysis, which was our first intention. Also, the available published information lacked quantitative data which could help to estimate the apparent prevalence of any reported disease in the province. The national database could provide different categories of qualitative data (the status of a particular animal disease being present or absent; the species, the year in which the disease was detected, the affected area and the number of the reported cases) whereas the WAHID interface could only provide the status of the animal disease being present or absent, the species and the period (year and month) in which the disease was detected. Hence this paper gathered information on diseases from Eastern Cape Province using both the national and the WAHID databases and assessed the validity of the information by comparing the findings from both.

The lack of census data in the province prevented the calculation of disease rates and comparison of years or any predictive modelling of the diseases of economic importance like Newcastle disease as was performed in Zambia (Mubamba et al., 2016). These constraints limited the work presented in this paper to a descriptive review of the data available on pig and poultry diseases in the Eastern Cape Province but served to highlight the major deficiency in disease reporting of pig and poultry diseases in this province that has long been present.

2.4.2 Reporting system and the role of provincial laboratories

In the Eastern Cape, animal disease detection in village communities depends largely on the passive surveillance of pigs and poultry due to lack of human and financial resources from veterinary services. Some surveillance occurs commercially using the private laboratories outside the province, but this targets primarily the commercial sector. It is therefore likely that non-controlled diseases are not reported especially when there is poor communication between the private sector (private veterinarians and private laboratories) and the provincial veterinary services. Active surveillance is compulsory only for export purposes (commercial farms) and is mainly for avian influenza and Newcastle disease (ostriches), Classical swine fever and African swine fever for pigs. The surveillance in the communal area (rural sector) depends on the availability of the budget and it is not done on a regular basis. The province is only equipped with three state veterinary laboratories which assist veterinary services in animal disease diagnostics and advise on the control and prevention. Unfortunately, these laboratories didn’t have a proper database which could be used extensively in this study. Only one laboratory could provide an electronic record of a few cases seen from 2012. It is important to mention that these provincial laboratories rely on the national laboratories for advanced diagnostic technologies, which sometimes cause a delay in finalising results and a delay in databases being updated. Private veterinarians can also send diagnostic samples directly to the national laboratory and receive results back without informing the local State veterinarians whose responsibility is to compile a comprehensive monthly report on controlled and notifiable diseases for their area. For controlled diseases however, the accredited diagnostic veterinary laboratory is obligated by a directive to inform the state veterinarian and DALRRD directly about the results at the same time the submitter receives them.

By reviewing the references from all databases of Web of Science, it was found that the number of references reporting on diseases on the communal farms was higher (42.3%) than the number of references reporting on diseases on the commercial farms (38.5%). The references reporting on diseases on both communal and commercial farms during the same study were 11.5% whereas three references representing 7.7% were reporting on a disease found in an abattoir. However, from the national database, it was impossible to establish whether the reported diseases were coming from the commercial or the communal farms.

By analysing the national database, the review found that Newcastle disease, coccidiosis and fowl pox were the most reported avian diseases whereas avian infectious bronchitis, Newcastle disease and highly pathogenic avian influenza (HPAI) were the most reported diseases from the WOAH database. For pig diseases, classical swine fever (CSF) was the most reported disease in both databases. It is suspected that these diseases were the most reported due to their outbreaks across the province in the previous years rather than active surveillance. The 2020 African swine fever (ASF) outbreak was not found in the national database but was found on the WAHID interface database; probably because there was no update of the national database during this review, which covers the period 1993 to 2019. The review highlights the fact that the national database is less accurate in recording non-controlled disease incidence, like Gumboro and avian infectious bronchitis, which are known to be endemic in the province (Simbizi, 2021) , because it is not mandatory to report these diseases.

The limited published data, particularly on non-controlled diseases in the Eastern Cape Province emphasises the need to encourage researchers to investigate animal diseases in the province.

2.4.3 Zoonotic diseases found in the review

A number of zoonotic diseases have been reported in the Eastern Cape Province. For avian influenza, a few studies identified the circulating strains (HPAI H5N2) in ostriches (Abolnik et al. 2009) and in chickens and wild birds (HPAI H5N8) (WOAH, 2020a) . The significance of this finding in terms of human health in the province is unknown.

Despite the high number of reported cases of Newcastle disease found in this study, there was no recent study investigating this disease and the circulating strains in the local poultry population. Such a study would help to understand the epidemiology of this disease for better prevention and control.

A few studies on cysticercocis (*Taenia solium*) in animals were done in the province but they seemed to be limited to two Districts (Alfred Nzo and OR Tambo) (Krecek et al. 2008; Krecek et al. 2012). This is surprising considering in 2004, an estimated 34,662 neurocysticercosis-associated cases of epilepsy were found in the ECP. The overall monetary burden (in millions of US$) was estimated to vary from US$ 18.6 to US$ 34.2 depending on the method used to estimate productivity losses (Carabin et al., 2006). Currently, this cost is likely to have increased given the fact that this study was done sixteen years ago. Another study on neurocysticercosis in the ECP had found that the Xhosa-speaking people of ECP had the highest prevalence of cysticercosis in South Africa probably due to the common practice of free-range pig farming and the lack of sanitation in these areas (Mafojane et al., 2003) as well as illegal slaughtering and selling of pig meats without prior meat inspection. The latter finding has been confirmed in a recent survey on trading practices of rural pig farmers in the province (Simbizi et al., unpublished).

The poor sanitation in the province and the use of swine waste as manure to improve the farm yields have been mentioned as risk factors for emerging pathogens like Hepatitis E (Adelabu et al. 2017) and Norovirus (Taku et al., 2017) found in this review. Such practices will also contribute to the propagation of diseases such as *Salmonella*, *Escherichia coli*, *Campylobacter* and *Enterococcus* infections found in this review and contribute to the risk of food poisoning in rural communities of ECP. These diseases become more significant when one considers the rate of HIV/AIDS infections in the province is among the highest in the country (Abong'o and Momba, 2008).

An interesting finding was the lack of reports on diseases that one would expect to be present. Diseases like leptospirosis would have been expected to be found given the large rural pig population in the province (STAT, 2016) and the fact that some serovars are maintained in pigs (Ellis, 2015). Eastern Cape economically being one of the poorest provinces of South Africa, the public health impact of these neglected diseases requires further investigation.

2.5 Conclusion

This paper reviews the current knowledge on pig and poultry diseases in the rural Eastern Cape Province with emphasis on data from 2000 to 2020. The study found that the retrieved literature was very scarce, and little has been published on pig and poultry diseases in the Eastern Cape Province. Hence decision makers don’t currently have reliable prior knowledge upon which to direct animal health interventions or implement one health public health programs aimed at reducing the incidence of zoonotic diseases. Important neglected diseases appear not to have been studied. An improved animal health information system and further targeted research based on this study is required to fill this gap in knowledge.

Poor communication between important disease reporting stakeholders in the province was reflected in the review through disparities in data sources and it is recommended that this be improved. Improved communication between the National department (DALRRD) and the National Institute of Communicable Diseases will increase awareness about the zoonotic diseases found in this review and help to minimise their impact on the livelihoods of the rural communities. It is recommended therefore, that a disease reporting system in the province involving all the stakeholders be considered to provide current relevant information on pig and poultry diseases. This will provide a foundation for sound decision making around disease control and international trade in live animal and animal products.

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CHAPTER 3

A STUDY OF RURAL CHICKEN FARMERS, DISEASES AND REMEDIES IN THE EASTERN CAPE PROVINCE OF SOUTH AFRICA

Publication

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ABSTRACT

The source of emerging diseases and antimicrobial resistance is of increasing interest to epidemiologists. This paper looks at village chickens as such a source. In addition, infectious diseases constitute a major challenge to the growth and profitability of the rural poultry sector in Sub-Saharan Africa. A serological survey was conducted to estimate the apparent seroprevalence of selected chicken diseases in the Eastern Cape Province of South Africa alongside a sociological survey of poultry farmers and the remedies most commonly used to prevent diseases in their flocks. Sera collected from village chickens (n=1007) in the province were screened for specific antibodies against Newcastle disease (ND), avian influenza (AI), avian infectious bronchitis (IB) and *Mycoplasma gallisepticum* (MG).

The overall seroprevalence of ND, AI, IB and MG in the province was found to be 69.2% (95% CI 51.9 - 86.5%); 1.8% (95% CI 0.2 - 3.4%); 78.5% (95 % CI 74.9 - 82%) and 55.8% (95% CI 41.3 - 70.3%) respectively with clustering found at the district level. Cross hemagglutination inhibition (HI) tests indicated that the chickens were exposed to the ND vaccine. AI ELISA-positive samples were tested using HIs against the H5, H6 and H7-subtypes, but only H6-specific antibodies were detected. Avian influenza strains shared the common ancestor responsible for the 2002 chicken outbreak in KwaZulu-Natal Province.

The majority of chicken farmers were females and pensioners (69% and 66.1% respectively) and had a primary school education (47.1%). Traditional remedies were commonly used by farmers (47.15%) and among the remedies, *Aloe* plant (*Aloe ferox* Mill.) or ikhala (Xhosa) was the most commonly used product (28.23%) for preventing and reducing mortalities among village chickens.

The findings stress the importance of village chickens as a substitute for social welfare and highlight the exposure of village chickens to important chicken pathogens. The economic impact of these pathogens on the development of this sub-sector needs further investigation. Village chickens are a potential source of virulent Newcastle disease virus (NDV) because of the lack of vaccination and biosecurity. They may serve as amplification hosts which increases the probability that virulent NDV could spill over into commercial poultry flocks due to large amounts of circulating virus. The zoonotic threat of circulating H6N2 viruses raise concern due to their mutation and reassortment among chickens and a potential movement of infected birds within the

province. Finally, the use of antibiotics by untrained chicken farmers constitutes another major concern as it could serve as a source of antimicrobial resistance (AMR).

Keywords: Chicken diseases, traditional remedies, antibiotic use, village farmers, emerging diseases

3.1 Introduction

In Southern Africa, village chickens are reared under an extensive or scavenging system and to a lesser extent in a semi-intensive system under subsistence farming, with few or no inputs for housing, feeding and health care (Mtileni et al., 2009). They play a vital role in many poor rural households by providing scarce animal protein in the form of meat and eggs and can be sold or bartered to meet essential family needs such as medicine, clothes and school fees (Alders and Pym, 2009). They are mostly owned and managed by women and children and are often essential elements of female-headed households (Gueye, 2000).

The Eastern Cape Province (ECP) is the second largest province in South Africa (**Figure 6**) and

Figure 6: Position of Eastern Cape Province and its District municipalities (Source: Wikipedia)

village chickens are reported to be the second most populous domesticated animal species in the province (STATS, 2016). The productivity of these chickens is however hampered by several factors, including a wide range of infectious diseases such as Newcastle disease (ND), avian influenza (AI), *Mycoplasma gallisepticum* (MG) Gumboro disease or infectious bursal disease (IBD), fowl cholera and avian infectious bronchitis (IB) (DAFF, 2020; Simbizi, 2020). In addition, village chickens could be a potential reservoir of these pathogens that could jeopardise the development of local semi-commercial poultry production (Chaka et al., 2012). The reverse is also true when spent hens from commercial farms are introduced into village settings (Musako and Abolnik, 2012).

Data on the prevalence of poultry diseases in the rural sector of Southern Africa is limited. Similarly, only a few studies on the demographics of rural chicken farmers and the remedies they use to treat infectious diseases have been published.

The objectives of this study were therefore to describe the demographics of village chicken farmers in the ECP, to describe the remedies used by farmers to treat and prevent chicken diseases and to determine the apparent seroprevalence of Newcastle disease (ND), avian influenza (AI), avian infectious bronchitis (IB) and *Mycoplasma gallisepticum* (MG), the important diseases affecting chickens in Southern Africa.

3.2 Materials and Methods

3.2.1. Study design

The Eastern Cape Province is divided into two metropolitan municipalities, Buffalo City and Nelson Mandela Bay, and six district municipalities (**Figure 6**). The district municipalities are in turn divided into thirty-one local municipalities. All thirty-one local municipalities plus the two metropolitan municipalities were included in the study. A two-stage sampling strategy was used to calculate the required number of villages and households to be used in the study (Thrusfield, 2005). Three villages per municipality were randomly selected, giving a total number of 99 villages for the whole province. Since the study design included a pig survey (data to be published elsewhere), a list of farmers with at least four chickens and four pigs was generated with the help of the extension officers and a sample of five households per selected village was randomly selected giving a total number of 15 households (or 15 farmers) per local municipality (approximately 500 households in total which could be divided into 250 chicken farmers and 250 pig farmers).

An interview-based questionnaire of households with village chickens was carried out by the research team with the assistance of veterinary and extension services from the Department of Rural Development and Agrarian Reform, Eastern Cape Province. A section on farm owner demographics (age of the farmers, sex etc.), farm husbandry (number of poultry kept, breed, farm raising system etc.) and poultry diseases and their treatment was included in the questionnaire.

3.2.2 Blood collection

The serological survey was conducted from August 2019 to March 2020 and targeted 500 households based upon the two-stage sampling strategy described. Two chickens from each household were sampled to give a total of approximately 1000 samples (Thrusfield, 2005).

Only non-vaccinated chickens were sampled. Blood samples were collected from the brachial vein in 3-mL disposable syringes and transferred into 10 ml blood collection tubes to allow the serum to separate before they were sent to the Queenstown Veterinary Provincial laboratory. Each tube was labelled with a unique number describing each chicken bled (sex, breed, age, owner's name and village name). At the laboratory, serum was collected in 2-mL cryovial tubes with a unique corresponding code and stored at −20°C until testing.

Serological tests

Sera were shipped to NOSA (Pty) Ltd in Centurion, Pretoria, a national accredited veterinary laboratory for serological testing. Sera were analyzed using commercial ELISA kits for the presence of antibodies to NDV (Newcastle Disease Virus Antibody Test Kit: BioChek, United Kingdom), AI (IDEXX Influenza A virus Antibody test; Montpellier SAS, France) and MG (IDEXX Mycoplasma Gallisepticum Test Kit; Montpellier SAS, France) according to the manufacturers' recommended procedures. For IB, the ELISA method to detected antibodies to IB was developed in-house. The NDV assay worked on the principle of indirect ELISA and was developed to detect specific antibodies against PMV-1 in serum. Microtitre plates were pre-coated with purified NDV antigens. Chicken serum samples were diluted and added to the microtitre wells where any anti-NDV antibodies present would bind and form antigen-antibody complex. Non-specific antibodies and other proteins were then washed away. Anti-chicken IgG labelled with the alkaline phosphatase were added to the wells to bind to any chicken anti-NDV antibodies bound to the antigen. After another wash to remove the unreacted conjugate, substrate was added in the form of *para*-

Nitrophenylphosphate (pNPP) chromogen. A yellow colour was developed when anti-NDV antibody was present. The intensity was related to the amount of the anti-NDV antibody present in the sample. The sample and control OD values were read using an ELISA reader at 405 nm. For each sample, the sample-to-positive (S/P) ratios were calculated from OD values by the formula:

S/P ratio = (OD_{sample} – negative control mean OD)/ (positive control mean OD-negative control mean OD). ND positive samples had an S/P > 0.2 whereas samples with an S/P ≤ 0.2 were regarded as negative.

The Influenza A assay was performed in a microtitre well coated with Influenza A viral antigen. During the first incubation, at room temperature, Influenza A antibodies present in the sample reacted with immobilized antigens. After a wash step, an Anti-Influenza A monoclonal antibody enzyme conjugate was added to the micro well. In the absence of any Anti-Influenza A antibodies in the sample, the enzyme-conjugated monoclonal antibodies were blocked from reacting with the antigen. Following this incubation period, the excess conjugate was removed by washing and a substrate/chromogen solution was added. In the presence of enzyme, the substrate was converted to a product which reacted with the chromophore to generate a blue colour. The absorbance was read at 620 nm using a spectrophotometer.

Results were calculated by dividing the OD value of the sample by the mean OD of the negative control, resulting in a sample to negative (S/N) value (S/N ratio=Sample OD/negative control OD). The quantity of antibodies to Influenza A was inversely proportional to the OD value, and thus, to the S/N value. The same principle applied to all IDEXX kit test for MG.

For the AI assay to be valid, the negative control optical density had to be ≥ 0.50 and the positive control S/N (sample to negative) had to be <0.5. Samples with S/N ratios ≥ 0.50 were therefore considered as negative whereas samples with S/N ratios <0.5 were considered as positive.

For MG, positive samples had an S/P ≥ 0.5 whereas samples with an S/P ≤ 0.49 were regarded as negative.

All ELISA AI positive samples were tested using the HI tests for H5/ H6/ H7 subtyping according to the WOAH-recommended protocol, with a cut-off of 2^2 or $>\log_2 2$ for a positive sample (WOAH, 2018a).

A sub-set of ELISA-positive ND samples (n=38) with titre $>2^2$ (or $>\log_2 2$ when expressed as the reciprocal) were tested with the cross haemagglutination inhibition

(HI) tests (WOAH, 2018b) using antigens that distinguish virulent genotype VII and avirulent genotype II. Cross-HI tests for NDV-specific antibodies were performed at the accredited Serology laboratory of the Department of Veterinary Tropical Diseases, University of Pretoria.

3.2.3 Data analysis

All data from the questionnaire were entered into the software programmes Epi Info® 7, NCSS and Microsoft Excel for statistical analysis. Data from the questionnaire were analysed using descriptive statistics. Apparent seroprevalence was computed by dividing the number of seropositive chickens by the total number of chickens sampled. Published values for specificity and sensitivity of the ELISA test (**Table 5**) were used to calculate the true prevalence and the 95% confidence interval (CI) of each disease using the Epi Tools Epidemiological calculators (http://epitools.ausvet.com.au).

Table 5: Characteristics of ELISA test used to calculate the true prevalence

Disease	Sensitivity	Specificity	Reference
ND	98.9	98.4	(Phan et al., 2013)
AI	98	98	(Shriner et al., 2016)
IB	98	97.2	(Chen et al., 2011)
MG	97.2	100	(Ewing et al., 1996)

Spatial analysis was done using ArcGIS Desktop 10.7® software by comparing the districts with the highest seroprevalence of ND, AI, IB and MG.

The overall seroprevalence and 95% confidence interval of selected disease in the province was calculated taking into account clustering within the data using Equation 1 and Equation 2 (Thrusfield, 2005).

$$\hat{P}-1.96\left\{\frac{C}{T}\sqrt{\frac{V}{C(C-1)}}\right\}, \hat{P}+1.96\left\{\frac{C}{T}\sqrt{\frac{V}{C(C-1)}}\right\}, \qquad \text{(Equation 1)}$$

Where:

C=number of clusters in the sample

T=total number of animals in the sample

and:

V= $\hat{P}^2(\sum n^2) - 2\hat{P}(\sum nm)+(\sum m^2)$, (Equation 2)

Where:

n=number of animals sampled in each cluster

m=number of diseased animals sampled in each cluster

3.3 Results

3.3.1 Demographics of village chicken farmers

Among farmers interviewed, females were more represented (69%) than males (31%). For the purpose of analysis, farmers interviewed were grouped into three categories according to their age: youth (from 18 - 35 years); adults (36 - 55 years) and pensioners (56 - 89). The survey showed that pensioners were more represented (66.1%; 95% CI 64.6 - 67.5) followed by the adults (46.4%; 95% CI 44.9 - 47.9) and youth (30.2%; 95% CI 27.9 - 32.6). The survey found that 47.1 % of farmers had primary education (from grade 1 - 9) followed by farmers with secondary education (grade 10 - 12) (37.1%); 7.1% of farmers had tertiary education and 8.6% of farmers had no education.

3.3.2 Farming system and remedies used to treat infectious diseases in village chickens.

The chicken production systems in this study were classified using the FAO family poultry production system classification guidelines (FAO, 2014). The study found that 40% of rural farmers were using a small extensive scavenging system, i.e., chickens that scavenge for food around the yard or village during the day with almost no supplementation and kept in poultry houses at night whereas 37.62% of farmers used an extensive scavenging system where poultry are allowed to wander around the village looking for food with occasional supplementation. A semi-intensive system, where chickens were always kept in a confined area with regular supplementation was used by 22.38% of rural farmers.

Farmers were using remedies for the prevention and treatment of chicken diseases which could be grouped into one of four groups: Sulpha products; Tetracyclines, traditional remedies and chicken vaccines (Appendix 8).

Traditional remedies were most commonly used by farmers (47.15%). Among this group, *Aloe* (*Aloe ferox* Mill.) was the most predominant product used (28.23%). The second group of medicines used by farmers was tetracyclines (17.42%) followed by the Sulpha products (12.01%). Farmers had access to these antibiotics as over-the-counter products through the local licensed selling companies. Chicken vaccines were the last group of remedies frequently used by farmers which comprised ND vaccine (6.91%); Gumboro (4.8%) and avian infectious bronchitis vaccine (0.9%) (Appendix 8). The study also found that Stresspac (Phenix ® Stresspac for Poultry and Ostriches: Virbac) was commonly used by chicken farmers as a supplement (10.33%) (Appendix 8). Seventy-eight farmers (37.1%) were using a combination of one or more of the above-mentioned remedies whereas 110 farmers (52.4%) were using only one of these products. Twenty-two farmers (10.4%) were not using any remedies for the prevention of chicken diseases.

3.3.3 Seroprevalence of chicken diseases

A total of 1007 village chickens from 71 villages in the ECP were sampled (Appendix 9). The ages of these chickens were ranged from 1 months to 6 years. Among these chickens, 120 were layers, 666 were Xhosa or local breed and 221 were broilers. The apparent prevalence of ND, AI, IB and MG was calculated at the district level with 95% CI (**Table 6**).

Table 6: Apparent prevalence of Newcastle disease (ND), avian influenza (AI), avian infectious bronchitis (IB) and *M. gallisepticum* (MG) in districts of the Eastern Cape Province (From August 2019 to February 2020).

Disease	District	Total no. collected	No. positives	Prevalence	95% CI*
ND	Chris Hani	411	231	56.2%	51.4 - 60.9%
	Alfred Nzo	88	83	94.3%	87.4 - 97.6%
	Joe Gqabi	66	60	90.9%	81.6 - 95.8%
	Buffalo City	34	33	97.1%	85.1 - 99.5%
	OR Tambo	96	93	96.9%	91.2 - 98.9%
	Sarah Baartman	84	82	97.6%	91.7 - 99.3%
	Amathole	228	115	50.4%	44 - 56.9%

AI	Chris Hani	411	6	1.5%	0.7 - 3.2%
	Alfred Nzo	88	7	8%	3.9 - 15.5%
	Joe Gqabi	66	0	0%	0 - 6%
	Buffalo City	34	0	0%	0 - 10.2%
	OR Tambo	96	4	4.2%	1.6 - 10.2%
	Sarah Baartman	84	1	1.2%	0.2 - 6.4%
	Amathole	228	0	0%	0 - 1.7%
IB	Chris Hani	411	325	79.1%	74.9 - 82.7%
	Alfred Nzo	88	73	83%	73.8 - 89.4%
	Joe Gqabi	66	50	75.8%	64.2 - 84.5%
	Buffalo City	34	29	85.3%	69.9 - 93.6%
	OR Tambo	96	63	65.6%	55.7 - 74.4%
	Sarah Baartman	84	62	73.8%	63.5 - 82%
	Amathole	228	188	82.5%	77 - 86.8%
MG	Chris Hani	411	197	47.9%	43.1 - 52.8%
	Alfred Nzo	88	61	69.3%	59 - 78%
	Joe Gqabi	66	39	59.1%	47 - 70.1%
	Buffalo City	34	31	91.2%	77 - 97%
	OR Tambo	96	74	77.1%	67.7 - 84.4%
	Sarah Baartman	84	78	92.9%	85.3 - 96.7%
	Amathole	228	82	36%	30 - 42.4%

*95% CI: Confidence interval calculated based on the sensitivity and specificity of the test (**Table 5**)

The overall seroprevalence of ND, AI, IB and MG in the province was found to be 69.2% (95% CI 51.9 - 86.5%); 1.8% (95% CI 0.2 - 3.4%); 78.5% (95 % CI 74.9 - 82%) and 55.8% (95% CI 41.3 - 70.3%) respectively.

The true prevalence of each selected disease at provincial level was calculated considering the clustering effect during the sampling. A cluster was considered as a batch of chickens originating from one household (**Table 7**).

Table 7: True prevalence of chicken diseases in the Eastern Cape Province (From August 2019 to February 2020) at provincial level

Disease	Number of positive samples	Apparent prevalence	True prevalence
Newcastle	697/1007	69.2%	51.9 - 86.5%
Avian influenza	18/1007	1.8%	0.2 - 3.4%
Avian infectious bronchitis	790/1007	78.5%	74.9 - 82%
Mycoplasma gallisepticum	562/1007	55.8%	41.3 - 70.3%

3.3.4 The cross-HI test results for ND positive samples

The results from the cross-HI test showed that 31 samples out of 38 from chickens exposed to the vaccine strains were identified by the Genotype II (avirulent vaccine) antigen giving a higher Log_2 HI titre in every instance, by 1 to 2 logs (Appendix 10).

3.3.5 The cross-HI test results for AI positive samples

Fourteen AI ELISA-positives samples were tested using HIs against the H5, H6 and H7-subtypes. Ten samples (ADA1; CAA1; HAA5; HCA1; ICA1; ICB2; PAA2; PAA4, PAA9 and PAA10) presented high titres to H6. Four samples (AFB 18; AFC11; AFD 11 and AFE6) were negative to all AI subtypes. One sample (ADA1) was strongly H6 positive as evidenced by reactions to the H6N2 and H6N8 antigens, the H5N2 reaction being a neuraminidase cross-reaction (N2). Eight samples (CAA1; HAA5; HCA1; ICA1; PAA2; PAA4; PAA9; PAA10) presented false positive results due to the contamination of the H5N6 antigen with the AviVac H6N2 vaccine seed strain (C. Abolnik 2023, personal communication) (Appendix 11).

3.4 Discussion

Village chickens were owned mainly by females (69%) compared to men (31%). The main reason for keeping chickens was for selling (income generation) and human consumption (meat and eggs). This was consistent with other findings published on village chickens (Mushi et al., 2000; Alders and Pym, 2009; Mtileni et al., 2012; Mtileni et al., 2013) stating that females dominate most of the activities around chicken production; feeding, watering, cleaning, selling of chickens and eggs. It also emphasizes the importance of poultry farming as an income source for women.

Among village chicken farmers' pensioners were the most represented compared to youth and adults and village chickens can be regarded as an important source of income for most pensioners, which is highly significant considering the virtual lack of welfare system in many African countries.

Farmers with only a primary school level of education were predominantly involved in chicken farming (47.1 %) compared to those with secondary and tertiary education level. This is similar to what was reported previously in two studies in the Eastern Cape Province (Nyoni and Masika, 2012; Idowu et al., 2018) and chickens are therefore an important source of income for a sector of the population that may find other employment opportunities difficult due to their low level of education.

A small extensive scavenging system was the most commonly used by village chicken farmers in the Eastern Cape Province (40%), compared to those using an extensive scavenging (37.62%) and a semi-intensive system (22.38%). This agrees with what was found in previous studies (Idowu et al., 2018; Mubamba et al., 2018) where it was shown that this system of farming is the most cost effective in that environment.

Traditional remedies were commonly used by farmers (47.15%) and among these, *Aloe* was the most predominant product used (28.23%). *Aloe* plants *(Asphodelaceae*) have been widely known and used for centuries due to their health, beauty, medicinal, and skin care properties (Boudreau and Beland, 2006). *Aloe arborescens*, *Aloe barbadensis*, *Aloe ferox*, and *Aloe vera* are among the well-investigated *Aloe* species and are among the most economically important medicinal plants commonly used in primary health treatment (Salehi et al., 2018). *Aloe ferox* Mill. or ikhala in Xhosa which was predominantly used by farmers in this study has been reported to be effective in the prevention of chicken diseases including ND (Waihenya et al., 2002a; Mwale et al., 2005) and *Salmonella gallinarum* (Waihenya et al., 2002b). Leaves are generally used and are prepared by crushing a leaf and mixing it with a litre of water

(Masimba et al., 2011). The solution is then given to the chickens until they show signs of good health (Mwale et al., 2005).

Seventy-eight percent (78%) of farmers interviewed reported "ikhala" prevented and reduced mortalities among village chickens. Tetracyclines and Sulpha products were the second group of remedies used by chicken farmers which could be explained by their low cost compared to other chicken remedies as well as their availability on the market. Their availability and use by untrained farmers are concerning as this could be contributing to antimicrobial resistance (AMR). These findings highlight the need for more detailed look at antibiotic use in these communities.

Chicken vaccines were only used by a small number of farmers and included ND vaccine (6.91%), Gumboro (4.8%) and avian infectious bronchitis disease (0.9%). The study demonstrated that chicken vaccines were not widely used by village chicken farmers probably due to lack of knowledge, availability of vaccines and inaccessibility of veterinary and extension services. This was consistent with the findings from similar studies in South Africa (Mtileni et al., 2009; Mtileni et al., 2012; Mtileni et al., 2013), Botswana (Mushi et al., 2000) and Zimbabwe (Kelley et al., 1994).

The overall seroprevalence of ND in the province was found to be 69.2% (95% CI 51.9 - 86.5%) (**Table 7** and **Figure 7**) but varied from 50.4% to 97.6% at the district level. Estimates of prevalence of ND across many SADC countries were reported somewhere else (Alders and Spradbrow, 2001).

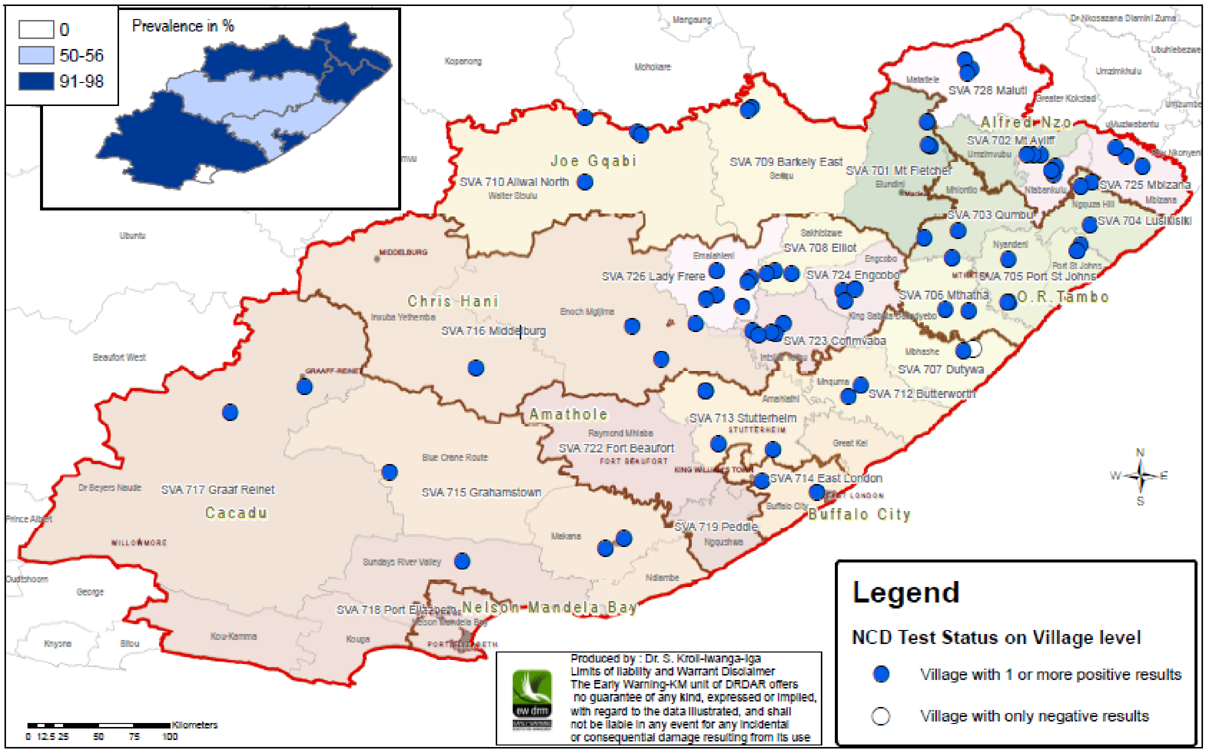

Figure 7: Apparent prevalence of ND at district level, ECP, from August 2019 to February 2020.

In South Africa, this prevalence was higher than that reported in the North West Province (Thekisoe et al., 2003). The samples were collected from apparently healthy, unvaccinated birds, suggesting that the infections were probably due to circulating avirulent strains and this was shown through cross-HI tests. The cross-HI assay for ND positive samples showed that antibodies identified by the LaSota antigen (II) had high titres compared to the ones produced by the N2057 antigen (VII). Different studies on the cross-HI tests have demonstrated antigenic differences between different NDV genotypes (Miller et al., 2007; Li et al., 2010). The live lentogenic LaSota vaccine strain is widely used in the commercial sector and it is possible that some spillover of vaccine strains into village chickens occurred, especially where spent layers end up in the village (Musako and Abolnik, 2012). Vaccinated birds exposed to virulent virus strains develop no clinical signs; however, some replication of the infecting virus occurs, and birds excrete virulent ND virus (Musako and Abolnik, 2012). The extent to which the propagation of these vaccine strains may have occurred still needs to be determined given the high and widespread seroprevalence found in this study. In the rural Eastern Cape, active vaccination of village chickens against ND is rarely practiced mainly due to the lack of knowledge from farmers, inaccessibility of veterinary and extension services and unavailability of the vaccines in remote rural area. Furthermore, this activity is not prioritized by veterinary services in the province. Our study therefore highlights the importance of village chickens as a potential source of emerging virulent strains of ND virus due to the lack of vaccination and biosecurity. Village chicken may serve as amplification hosts which increases the probability that virulent NDV could spill over into commercial poultry flocks due to large amounts of circulating virus (Brown and Bevins, 2017). Vaccinated chickens can also play a role as a reservoir for virulent strains of NDV because they can become infected with virulent strains following vaccination and shed infectious virus in the absence of clinical disease (Miller et al., 2010).

The overall seroprevalence of AI in the province was found to be 1.8% (95% CI 0.2 - 3.4%) (**Table 8** and **Figure 8**) but varied from 0% to 8% at the district level.

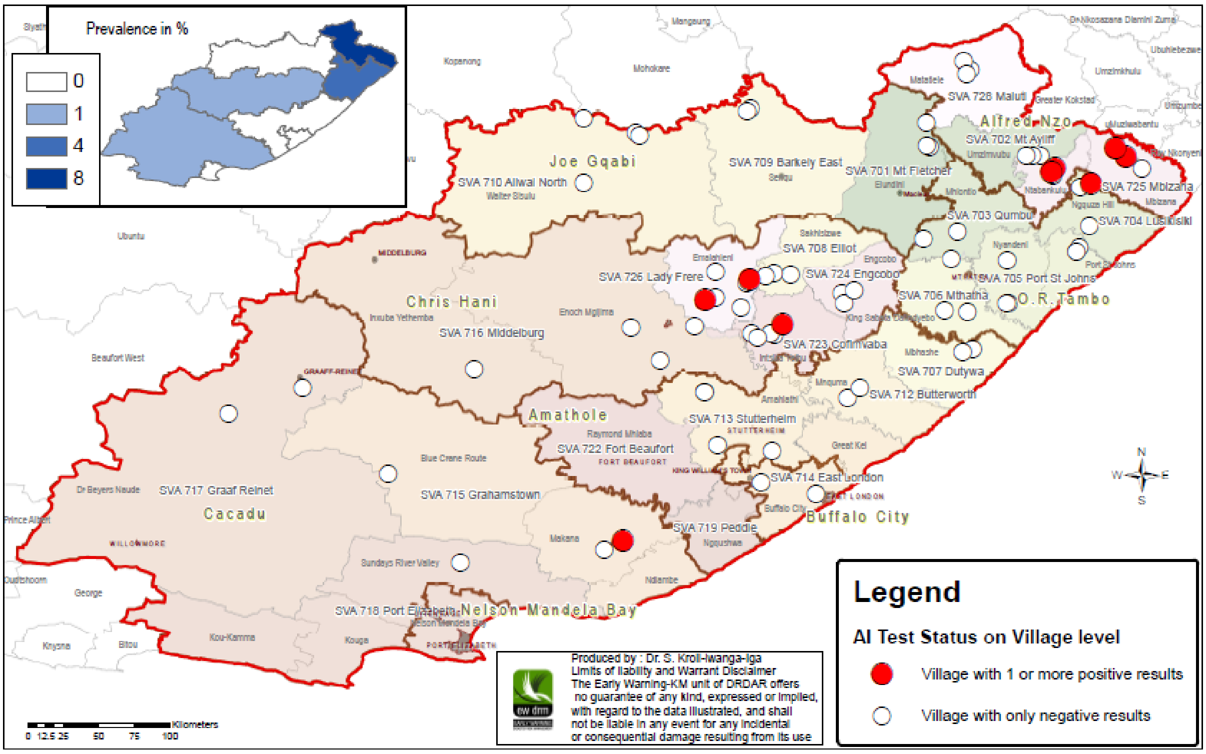

Figure 8: Apparent prevalence of H6 avian influenza at district level, ECP, from August 2019 to February 2020.

This was in agreement with a recent work which reported a varied regional prevalence in Sub-Saharan Africa ranging from 1.1% to 7.1% (Kalonda et al., 2020). AI ELISA-positive samples were tested using HIs against the H5, H6 and H7-subtypes, but only H6-specific antibodies were detected. It was found that these H6-specific antibodies were circulating in chickens from Alfred Nzo District which had a highest prevalence of AI. This is not surprising since this is the closest District to KwaZulu-Natal Province where an outbreak of H6N2 occurred: South Africa's H6N2 epidemic in chickens began in 2001. The progenitor was traced to a reassortment between viruses that infected commercial ostriches in the Western Cape Province in the mid to late 1990's notably an H6N8 virus and an H9N2 virus. The disease later spread to KwaZulu-Natal (Camperdown area) and to other provinces (Abolnik et al., 2007). The movement of infected chickens between Alfred Nzo and its neighbouring District in KwaZulu-Natal could explain this high prevalence.

The threat of poultry-origin H6 avian influenza viruses to human health emphasizes the importance of monitoring their evolution. The true incidence and prevalence of H6N2 in the country has been difficult to determine, partly due to the continued use of an inactivated whole virus H6N2 vaccine and the inability to distinguish vaccinated from non-vaccinated birds on serology tests (Abolnik et al., 2019). A recent study found that the H6N2 viruses in South African chickens are mutating and reassorting amongst themselves but have remained a genetically pure lineage since their emerging. Greater efforts must be made by government and industry in the continuous isolation and characterization of field strains for use as HI antigens, new vaccine seed strains and to monitor the zoonotic threat of H6N2 viruses (Abolnik et al., 2019).

All sampled poultry were free of respiratory symptoms at the time of sampling and many farmers did not confirm the use of IB vaccine during the interview (0.9%). The apparent prevalence of IB found in this study [78.5% (95% CI 74.9 - 82%)] (**Table 7** and **Figure 9**) was higher than reported by Thekisoe et al. (2003) in QwaQwa in South Africa.

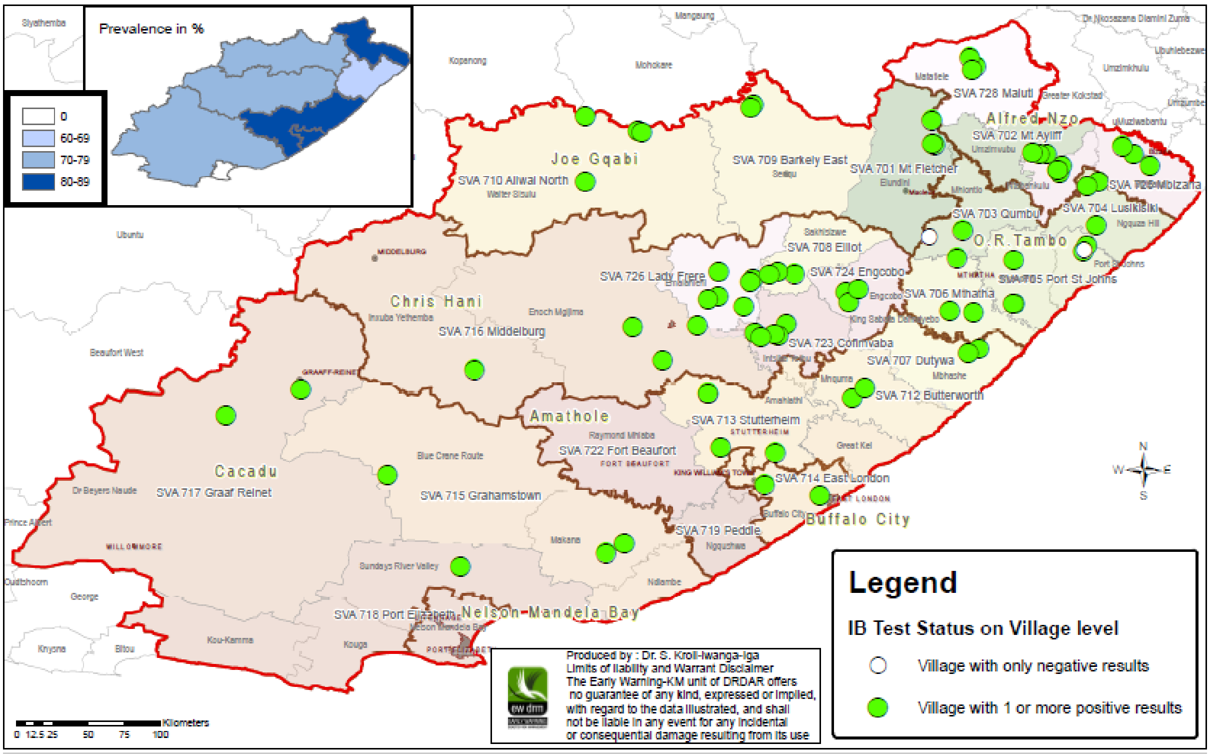

Figure 9: Apparent prevalence of avian infectious bronchitis at district level, ECP, from August 2019 to February 2020.

Variations in prevalences between other SADC countries were also noticed. The highest prevalence (86%) was found in backyard chicken flocks of Chitungwiza, Zimbabwe (Kelley et al., 1994) whereas in Botswana, the seroprevalence of IB in backyard chickens was found to be 34.78% (Mushi et al., 2000). The difference in seroprevalence between various region might be explained by different types of biosecurity, management practices, vaccination status, environmental factors as well as the sample size. Although the present study could not identify different strains of IB, the range and magnitude of the serological results provided evidence to suggest exposure of the birds to IBV circulating within the local chickens. A QX-like IBV strain has been isolated in the province (Knoetze et al., 2014) but it is not clear whether it was the same strain circulating among village chickens. Ideal management which include strict isolation, high biosecurity and repopulation following the cleaning and disinfection of the poultry house and equipment as well as immunization in an attempt to prevent production losses (Jackwood and de Wit, 2013) would be of great importance.

The overall seroprevalence of *Mycoplasma gallisepticum* in this study was found to be 55.8% (95% CI 41.3 - 70.3%) (**Table 7** and **Figure 10**) at the provincial level and varied between 36% and 92.9% at the district level.

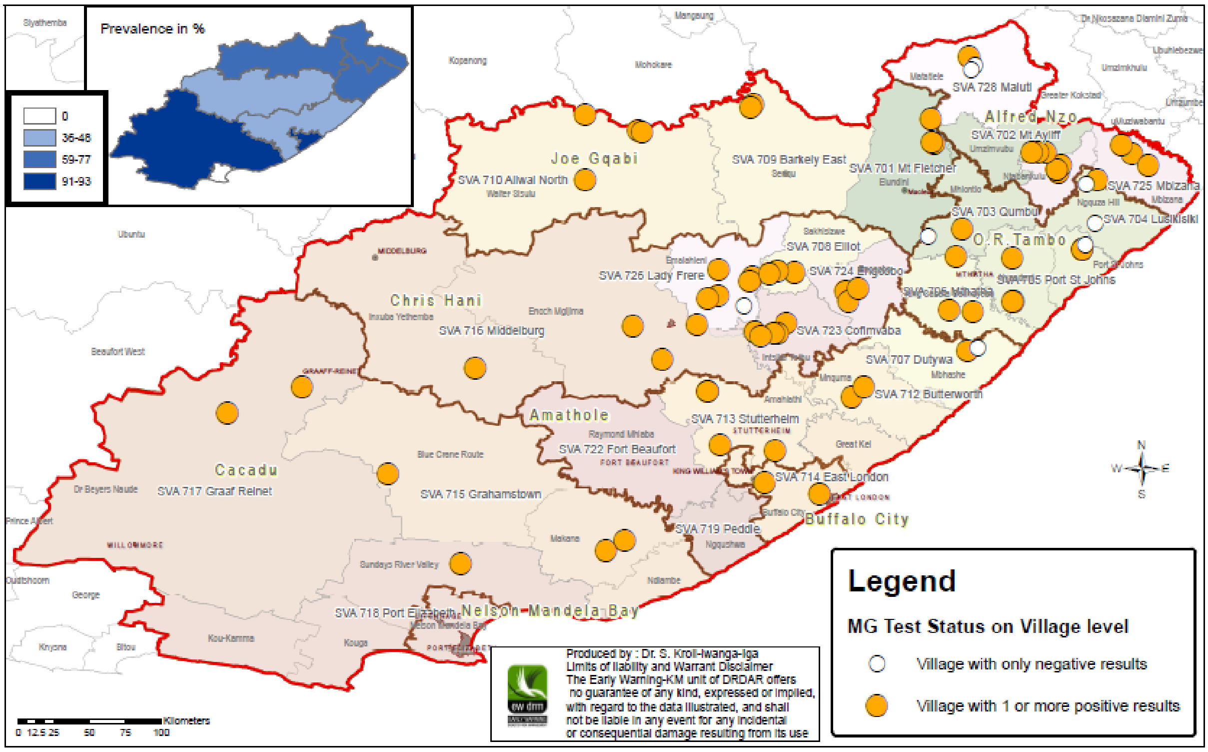

Figure 10: Apparent prevalence of *M. gallisepticum* at district level, ECP, from August 2019 to February 2020.

Based on these results, it appears that MG infection may be endemic in the village chickens of Eastern Cape Province and since it can be egg transmitted, its control may be difficult. The survey showed that farmers didn't have enough knowledge on the respiratory diseases of chickens, and the use of the vaccine was very limited. Prevention and control programs, which may include surveillance (isolation and identification, serology, molecular detection and characterization), vaccination, and eradication of infected breeding stock should be prioritized if policymakers want to improve the rural poultry sector in the province.

3.5. Limitation

The limitation of serological tests, as used in this study to confirm exposure to ND, is they cannot differentiate antibodies induced by an infection from those induced by vaccination with live or inactivated vaccines (Thayer and Beard, 2008). Hence prevalence estimates will be influenced by this but due to low vaccination rates in this study the bias is likely to be small. As with all prevalence studies, the time when chickens were exposed to the agent cannot be accurately determined in this study. Another limitation is that the questionnaire interview took almost 5 months to be completed (From February to June 2019). The serological survey started one month later. By the time the serological survey started, not every household interviewed had chickens to be used in the survey (some were consumed or sold) hence the targeted number of 250 households in the study design could not be reached. This study could not establish any seasonal patterns of the selected chicken diseases as the study was designed to measure the point prevalence of disease and not incidence over time.

3.6 Conclusion

This is the first serological survey done in the village chickens of Eastern Cape Province, which determined the seroprevalence of ND, AI, IB and MG infections. The study found a high seroprevalence of ND, IB, and MG infections in village chickens. However, the economic impact of these infections on the growth of local poultry sector still needs to be determined. This study has also identified antibodies against the H6N2 subtypes of AI circulating in these chickens. These viruses were responsible for the 2002 chicken outbreak in KwaZulu-Natal and due to their zoonotic threat, efforts must be made to monitor their evolution. The survey found that village chickens were susceptible to virulent NDV because of the lack of vaccination and biosecurity. They may therefore serve as amplification hosts which increases the probability that virulent NDV could spill over into commercial poultry flocks due to large amounts of circulating virus. The use of "ikhala" (*Aloe*) in the prevention of chicken diseases was confirmed through the questionnaire interview but its efficacy on these selected diseases was not specified. The availability and use of antibiotics by untrained farmers was another concern found as this could be contributing to antimicrobial resistance (AMR). The findings highlight the importance of village chickens as a social health care system through income generation. Although this study had some limitations, it provides important baseline information on the prevalence and significance of selected infectious diseases in village chickens and the importance of sociological and environmental factors that may contribute to the emergence of diseases and antimicrobial resistance within village communities.

3.7 Ethical considerations

Permission to conduct this study was obtained from the Directorate of Veterinary Services, Department of Rural Development and Agrarian Reform in the Eastern Cape Province of South Africa. Ethical approvals to use live chickens and to interview village chicken farmers were obtained from the University of Pretoria: animal use and care committee (V038-18) and the Faculty of Humanities (GW20180835HS).

3.8 Acknowledgements

This research study was conducted in partnership between the Directorate of Veterinary Services of Eastern Cape Province, South Africa; the Department of Production Animal Studies, University of Pretoria (South Africa) and the College of Public Health, Medical and Veterinary Sciences, James Cook University (Australia). The project received funding support from the South African branch of World Veterinary Poultry Association and from the National Research Foundation-Department of Science and Innovation grant no N00705/114612. We are most grateful to Kevin Dusubana and Mthetheli Stafans for helping with the questionnaire survey and capturing of data. We are also grateful to all extension officers and veterinary officials who helped in organizing farmers. We also thank the Queenstown provincial veterinary laboratory for the storage of chicken sera before analysis. Finally, we thank Dr Sabine Lwanga-Iga from producing the maps.

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CHAPTER 4

THE ROLE OF SMALLHOLDER PIG FARMERS IN THE BIOSECURITY OF PIG DISEASES IN THE EASTERN CAPE PROVINCE OF SOUTH AFRICA USING AFRICAN SWINE FEVER AS A MODEL

Publication

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ABSTRACT

African swine fever (ASF) is an important disease and a threat to the global pig industry. The Eastern Cape Province (ECP) of South Africa has experienced outbreaks of ASF from May 2020 but data on the demographics and practices of smallholder pig farmers are scant, and little is published on the biosecurity related to these farms. Similarly, there is little published on ASF prevalence in smallholder pig farms. A questionnaire survey was therefore carried out to describe the demographics and practices of smallholder pig farmers to understand their role in biosecurity and prevention of pig diseases using ASF as a model. In parallel, a survey of pigs was conducted to estimate the seroprevalence of ASF at provincial level. A total of 1000 pig sera were collected.

Females represented 52% of pig farmers and reflect the cultural importance of pig farming in Xhosa culture. All the farmers interviewed implemented low level of biosecurity measures on their farms. A low level of education, lack of training and reliance on the use of local remedies to treat and prevent pig diseases for many farmers were findings that could explain the poor implementation of biosecurity measures. Furthermore, poor knowledge of antibiotic use could contribute to antimicrobial resistance (AMR) in these pigs. Smallholder farms were frequently involving free-ranging pigs, swill feeding and informal trading; practices known to contribute to the spread of ASF and other communicable pig diseases. Our findings show that smallholder pig farming could therefore be a source of high-risk disease incursion and spread. The seroprevalence of ASF was found to be 0.01% (95% CI 0 - 0.015). Cost-effective biosecurity measures and marketing opportunities will help to prevent pig diseases while a continuing education programme will modernise the rural pig industry and reduce the impact of AMR.

Keywords: African swine fever, communicable pig diseases, smallholder pig farmers, biosecurity, remedies, practices

4.1 Introduction

Biosecurity measures for smallholder pig farms in the ECP of South Africa and in many Sub-Saharan African countries remain a challenge. In the absence of vaccines for some pig diseases (such as ASF) or their inaccessibility by resource-poor farmers, improved biosecurity is still the only way to achieve disease prevention, stop transmission and control outbreaks. In the context of this paper we refer to biosecurity at a farm level, i.e., measures aiming to prevent diseases from entering into a farm or a population, and to reduce transmission between individuals or groups of individuals once introduced (Penrith et al., 2021). Biosecurity measures applicable to smallholder pig farmers should be risk-based, feasible, affordable, socio-culturally acceptable and cost-effective (Penrith et al., 2021).

The increasing human population within Southern African countries, has put pressure on all stakeholders to improve on income generation and food security. As part of a response by the rural poor communities and taking into consideration the low capital investment needed for the informal pig keeping, there has been a steady increase in the number of smallholder pig farming (Penrith et al., 2013; Penrith et al., 2019; van Rensburg et al., 2020). The systems in which pigs are produced determine the level of risk for communicable pig diseases like ASF. In high-contact pig populations, for instance where there are free-ranging pigs, the rapid reproduction rate of pigs provides a constant supply of susceptible pigs to maintain the circulation of pathogens like ASF virus (ASFV) (Penrith et al., 2007). The risk of ASF to domestic pigs that are permanently confined, varies according to the level of management, while the risk to free-ranging populations will always be higher (FAO, 2011). Outdoor husbandry approaches vary significantly from traditional free-ranging pig production in developing countries, to more modern pig production in developed countries. Looking specifically at Africa; many rural areas where ASF is endemic, the majority of pigs are kept in low numbers by poor people that trade in the local market and practise fully or partial free-ranging systems, with varying degrees of management input (Mashatise et al., 2005; Penrith et al., 2007; Kagira et al., 2010; Mutua et al., 2011; Penrith et al., 2021). Outbreaks of ASF in Africa can be attributed to an increase number of smallholder and backyard farms where large-scale commercial pig farms are relatively rare (Mulumba-Mfumu et al., 2019). The periodic release of confined pigs to scavenge, may contribute to the involvement of backyard farms in the spread of disease, when the released pigs encounter free-range pigs. When the pigs are permanently confined and must be fed, food waste fed as swill is often the most important source of infection (Nantima et al., 2015), particularly in urban and peri-urban conditions, where leftover food from commercial food outlets is easily available (Dione et al., 2017).

In the context of backyard farms, another source of infection includes fomites introduced via people with unrestricted access to the farm (Zani et al., 2019) and the sale of pigs from farm to farm (Kabuuka et al., 2014).

The first outbreaks of ASF in the Eastern Cape Province (ECP) were reported in Mnquma municipality from May 2020, with subsequent reported outbreaks in Great Kei and Buffalo City Metropolitan municipalities also in 2020, and in King Sabata Dalindyebo (KSD), Ngcobo, Ngqushwa and Nelson Mandela Bay Metropolitan municipalities in 2021. These outbreaks occurred in the free-roaming, communal and smallholder pig sector (DALRRD, 2021, 2022). These outbreaks were caused by ASFV genotype II (DALRRD, 2021), responsible for many outbreaks in the Southern African Development Community (SADC) region (van Heerden et al., 2017; Quembo et al., 2018; Simulundu et al., 2018; Penrith et al., 2019; Hakizimana et al., 2020; Njau et al., 2021) and in Eurasia after its spread from Eastern Africa to Georgia in 2007 (Rowlands et al., 2008; Njau et al., 2021). A domestic pig cycle among free ranging pigs, as described in West Africa (Brown et al., 2018), may also be occurring in the ECP, therefore a more in depth look at the role of biosecurity in smallholder farms is warranted.

There are few studies on communicable pig diseases (zoonosis) in smallholder communities of ECP and those that have been published only focus on a limited number of districts and provide little information on biosecurity of smallholder pig farms in the province (Mafojane et al., 2003; Krecek et al., 2008; Krecek et al., 2012).

Similarly, limited studies on the demographics and practices of smallholder pig farmers in the ECP have been conducted (Madzimure et al., 2014; Sithole et al., 2019; Taruvinga et al., 2022), and there is currently no active surveillance for pig diseases like ASF in rural domestic pigs. The last provincial serological survey of ASF was done in 2013 and yielded negative results (De Klerk, 2014). Hence, little is known about disease transmission and biosecurity within the rural pig farming sector of the ECP. Because ASF is a highly contagious pig disease of economic importance, it was decided to use this viral disease as a model for how similar diseases may be handled within these smallholder farming communities. The objective of this study was therefore i) to use a questionnaire survey to describe the demographics and farm practices of smallholder pig farmers in the province to illustrate their role in biosecurity and prevention of pig diseases and ii) to estimate the seroprevalence of ASF at provincial level.

4.2 Materials and Methods

4.2.1 Study design

4.2.1.1 General overview

The study comprised two parts, an interview-based questionnaire survey targeting smallholder pig farmers in the ECP conducted from February to June 2019 and a serological survey of ASF conducted from August 2019 to May 2020. These components were separated for logistic reasons but still centred on the objective of gaining more information on the animal health practices of smallholder pig farmers in the province. The serological survey occurred incidentally at the time the first outbreaks of ASF were reported in the province and were not part of these disease outbreak investigations.

4.2.1.2 Study area

The study area was the whole of the ECP. The province has a human population of 6,676,590 people (STATS, 2021b), with a density of 39 people /km². The main language is Xhosa and the province is economically the poorest province in South Africa and has the highest unemployment rate in the country (STATS, 2021a). The province is divided into two metropolitan municipalities, viz. Buffalo City and Nelson Mandela Bay and six district municipalities. The district municipalities are in turn divided into thirty-one local municipalities. All thirty-one local municipalities and two metropolitan municipalities were included in the study (Figure 2). The informal pig sector in the ECP is estimated to have 536 108 pigs (STATS, 2016), most of which are found in the 6024 villages scattered throughout the province (Census, 2011).

4.2.2 Sampling procedure

A two-stage sampling strategy was used to calculate the required number of villages and smallholder pig farmers to be used in the study (Thrusfield, 2005). The criteria used for this sampling strategy was guided by the way the province is divided in terms of districts, municipalities and villages. Three villages per municipality were randomly selected in the first stage, giving a total number of 99 villages that were surveyed in the entire province. Since the study design also included a serological survey of chicken diseases (Simbizi et al., 2021), a list of smallholder farms with at least four chickens and four pigs was generated with the help of the agricultural extension officers and a sample of five farms from each first stage selected village was randomly selected, resulting in 15 smallholder pig farms per local municipality. The total number of smallholder farms required in the final stage was therefore 495, which was rounded to 500 farms and divided into 250 chicken farms and 250 pig farms. An interview-based questionnaire of the owners of the smallholder pig farms was carried out by the research team with the assistance of veterinary and agricultural extension services from the Department of Rural Development and Agrarian Reform. The questionnaires were developed in English and translated into isiXhosa for delivering to respondents. The questionnaire was pretested, and its validation was done through consultation with state veterinarians and animal health officials working in the areas being surveyed. The consultation with these officials involved feedback on the questions asked, to check if they were understandable and relevant. These officials also had an opportunity to complete the questionnaires themselves and give feedback. The authors further validated the questionnaires by including questions that were common to all questionnaires and comparing them during the final analysis of data. Sections on farm owner demographics (gender, age, level of education) and farming practices related to the spread of ASF which included farming systems and use of swill, contact with African wild suids, trading practices and biosecurity measures to prevent pig diseases were included in the questionnaire. Questions related to pig diseases and their treatment over the past 12 months were also included in the questionnaire. For biosecurity measures, farmers were asked if they had measures in place to prevent or control diseases on their farms. They were thereafter asked to give details about the nature of these measures if the response was “yes”. A list of biosecurity measures applicable to smallholder pig farms is given in Appendix 13. Detailed information on trading practices and value chain were also collected but are dealt with in a separate paper (Simbizi et al., unpublished).

4.2.3 Sample collection

Pigs from smallholder farms were bled across ECP (Appendix 12) between August 2019 and May 2020. Blood samples were collected from apparently healthy pigs managed under intensive, semi-intensive and free-range husbandry systems. On average, the pigs sampled were between 2 months and 4 years old. Blood samples were collected via venous puncture using sterile vacutainer tubes and needles (vacutainer tubes: BD vacutainer® CAT REF 368815; needles: BD vacutainer® Precision Glide ™ REF 360213). Samples collected were transported on ice to the Queenstown Veterinary Laboratory. At the laboratory, each serum sample was transferred into 2 ml Cryovials tubes (Vacutec®, Biologix 81-8204) with a unique corresponding code and stored at -20°C until transported to the FMD Reference Laboratory of Transboundary Animal Diseases (TAD) at the Onderstepoort Veterinary Research, Agricultural Research Council in South Africa, where they were tested for ASF antibodies. Samples were packed according to the regulatory requirements for the transport of biological goods, which comprised a sealed polystyrene cooler box with ice blocks inside, used for the shipment of frozen samples.

4.2.4 Serological testing (ELISA)

Tests for antibody to ASFV p72 protein in serum samples were performed using the World Organization for Animal Health (WOAH)-recommended INgezim PPA Compac R.11.PPA.K3 blocking enzyme-linked immunosorbent assay (ELISA) kits (Eurofins Technologies Ingenasa, Madrid, Spain) as per the manufacturer's instructions. The specificity of the test was reported to be 99.4% (Bergeron et al., 2017) and the sensitivity 77.2% (Gallardo et al., 2015).

4.2.5 Data analysis

All data from the questionnaire were entered into the software programmes Epi Info® 7, NCSS® and Microsoft Excel for statistical analysis. Data from the questionnaire were analysed using descriptive statistics. Fisher's Exact Test was used to determine the statistical difference between the number of males and females interviewed (NCSS, 2022). Apparent seroprevalence was computed by dividing the number of seropositive pigs by the total number of pigs sampled. Published values for specificity and sensitivity of the ELISA test were used to calculate the true prevalence of ASF at district level and the 95% confidence interval (CI) using the Epi Tools Epidemiological calculators (http://epitools.ausvet.com.au).

Spatial analysis was done using ArcGIS Desktop 10.7® software by plotting the areas where ELISA positive and negative samples were found.

The overall provincial seroprevalence and 95% confidence interval of ASF was calculated taking into account clustering within the data using Equation 1 and Equation 2 (Thrusfield and Christley, 2018).

$$\hat{P}-1.96\left\{\frac{C}{T}\sqrt{\frac{V}{C(C-1)}}\right\}, \hat{P}+1.96\left\{\frac{C}{T}\sqrt{\frac{V}{C(C-1)}}\right\}, \qquad \text{(Equation 1)}$$

Where: $\hat{P}$ =sample prevalence

C=number of clusters in the sample

T=total number of animals in the sample

and:

$$V= \hat{P}^2(\sum n^2) - 2\hat{P}(\sum nm)+(\sum m^2), \qquad \text{(Equation 2)}$$

Where:

V=variance between clusters

n=number of animals sampled in each cluster

m=number of diseased animals sampled in each cluster

4.3 Results

4.3.1 Demographics of smallholder pig farmers interviewed.

Among 214 smallholder farmers interviewed, 111 were females (52%) and 103 were males (48%) (P=0.44) confirming that the survey had more females than expected. For analysis, farmers interviewed were grouped into three categories according to their age: young adults (from 18 to 35 years); adults (36 - 55 years) and pensioners (56 - 89). Pensioners were more represented (52.3%) followed by adults (36%) than young adults (11.7%). The largest proportion of smallholder pig farmers (40.7%) had primary education (from grade 1 - 9) followed by farmers with secondary education (grade 10

- 12) (35%). About 14.5% of smallholder pig farmers had tertiary education (the highest level) whereas 9.8% of farmers had no formal education (**Table 8**).

4.3.2 Farming practices related to poor biosecurity in the province.

4.3.2.1 Farming system and use of swill

The survey revealed three types of feed used by pig smallholder farmers: commercial feed, supplements (crushed maize) and kitchen waste (swill). The present survey found that 72.4% of smallholder pig farmers confined pigs in one area, fed them using commercial feed with regular supplementation (intensive system), while 17.8% housed and fed their pigs using commercial feed with occasional supplementation but allowed them to move around the farm to scavenge within an enclosed area within the farm area (semi-intensive system) and 8.4% allowed their pigs to scavenge around the village or beyond with no proper housing, feed or supplementation (free range system) (**Table 8**). Some smallholder pig farmers (1.4%) did not specify how their pigs were managed. A large proportion (75.7%) of smallholder pig farmers were using kitchen waste (swill) in addition to the commercial feed and supplements (**Table 8**).

4.3.2.2 Contact of domestic pigs with African wild suids

The number of farmers who confirmed that their pigs were sharing a common habitat with African wild suids were 12 out of 214 representing 5.6% (**Table 8**).

4.3.2.3 Trading practices

The percentage of farmers involved in trade of pigs on a regular basis (every six months or less) was 15.9% whereas those who were not regularly selling pigs represented 48.1 %. The percentage of farmers selling pigs through auctions was 0.9%. None of the farmers (0%) obtained a movement permit or a health certificate from veterinary services before trade (**Table 8**).

4.3.2.4 On farm biosecurity and disease prevention practices

All the farmers interviewed had low biosecurity measures in place to prevent the potential entry of pig diseases into the farms. Instead, they used remedies to treat any signs of disease in pigs. Remedies used by smallholder pig farmers to treat or prevent pig diseases were subdivided into six categories: traditional, antibiotic, antiparasitic, acaricide, anthelmintic and vitamins and minerals. The most representative category of remedies was antibiotics used by 31.1% of farmers, followed by traditional remedies, used by 18.5% of farmers. Farmers who used antiparasitic drugs represented 15.6% of farmers, whereas those who used vitamins and minerals, acaricide and anthelmintics represented 6.6%, 4%, 2.3% of the farmers respectively. Farmers who did not report the use of any remedies to treat pig diseases made up 21.9% of the farmers (**Table 9**).

Table 8: Demographics and farming practices identified during the survey in the Eastern Cape Province (February-June 2019).

Demographics	**Percentage of respondents**
1. Gender	
Females	52% (111/214)
Males	48% (103/214)
2. Age	
Young adults (0-35)	11.7% (25/214)
Adults (36-55)	36% (77/214)
Pensioners (56-89)	52.3% (112/214)
3. Level of education	
None	9.8% (21/214)
Primary (grade 1-9)	40.7% (87/214)
Secondary (grade 10-12)	35% (75/214)
Tertiary	14.5% (31/214)
Farming practices	
1. Farming systems	
Intensive	72.4% (155/214)
Semi-intensive	17.8% (38/214)
Free range	8.4% (18/214)
Not specified	1.4% (3/214)
2. Feeding of swill	75.7% (162/214)
3. Contact with African wild suids	5.6% (12/214)
4. Selling pigs through auctions	0.9% (2/214)
5. Trading activity on a regular basis (every six months or less)	15.9% (34/214)
6. Trading activity at least once a year	48.1 (103/214)
7. Movement permit or health certificate before trade	0% (0/214)

Table 9: Remedies used by smallholder pig farmers in the Eastern Cape Province according to the survey done between February-June 2019

Category	**Remedies**	**Active ingredient**	**Frequency of usage (%)**
Not using any remedy*	–	–	
Antibiotics**:			
Tetracyclines	Terramycin, Hi-Tet	Oxytetracycline HCl	18.2%
Sulpha products	Norotrim	Sulphonamide	11.9%
	Sulfazine	Sulphadimidine Sodium	16%
Penicillin	Duplocillin	Procaine benzylpenicillin	1%
Traditional	Sibabile,	Unknown	18.5%
	Zifozonke,	Sodium permanganate,	
	Madubula	Tar acid	
	Ashes	Unknown	
	Salt	Sodium chloride	
	Sunlight soap	Unknown	
	Engine oil	Unknown	
	Epsom salts	Magnesium sulfate	
	Aloe ferox Mill.	Cape Aloe Ferox Gel, Vitamins C, B5, A, E, B6 and B2	
	Sugar		
Antiparasitic macrocyclic lactones	Dectomax, Ivermax	Ivermectin	15.6%
Vitamins and minerals	Multivite, Calcium, Iron Dextran	Vitamins A, B, C, Calcium, Iron hydrogenated Dextran	6.6%
Acaricide	Dazzel NF	Diazinon 30% m/v	4%
Anthelmintic	Piperazine salts	Piperazine citrate	2.3%

*Farmers who were not using any remedy to treat pig diseases represented 21.9%

**Combined antibiotic use (tetracyclines, sulpha products and penicillin): 31.1%

4.3.3 Seroprevalence of ASF in the province (August 2019-May 2020).

The total number of blood samples collected was 1000 originating from pigs in 239 smallholder farms (Appendix 1). The overall seroprevalence of ASF in the province was 0.01% (95% CI 0 - 0.015) with clustering found at the district level because some districts presented with a higher number of collected samples than others (Appendix 12). Seropositive samples were found in Sarah Baartman and Amathole Districts (**Figure 11**). The apparent prevalence of ASF in Sarah Baartman and Amathole Districts was 0.003% (95% CI 0.001 - 0.02) and 0.03% (95% CI 0.01 - 0.07) respectively (**Table 10**).

Table 10: Apparent prevalence (AP) of ASF in the ECP between August 2019 and May 2020

District	Number of samples	Number positive	AP (%)	95% CI*
Chris Hani	147	0	0	0 - 0.03
Alfred Nzo	126	0	0	0 - 0.03
Joe Qabi	56	0	0	0 - 0.06
Buffalo City	28	0	0	0 - 0.12
OR Tambo	107	0	0	0 - 0.03
Sarah Baartman	349	1	0.003	0.001 - 0.02
Nelson Mandela Bay	21	0	0	0 - 0.15
Amathole	166	5	0.03	0.013 - 0.069

*Confidence interval (CI) calculated based on the specificity of 99.4% and a sensitivity of 77.2%

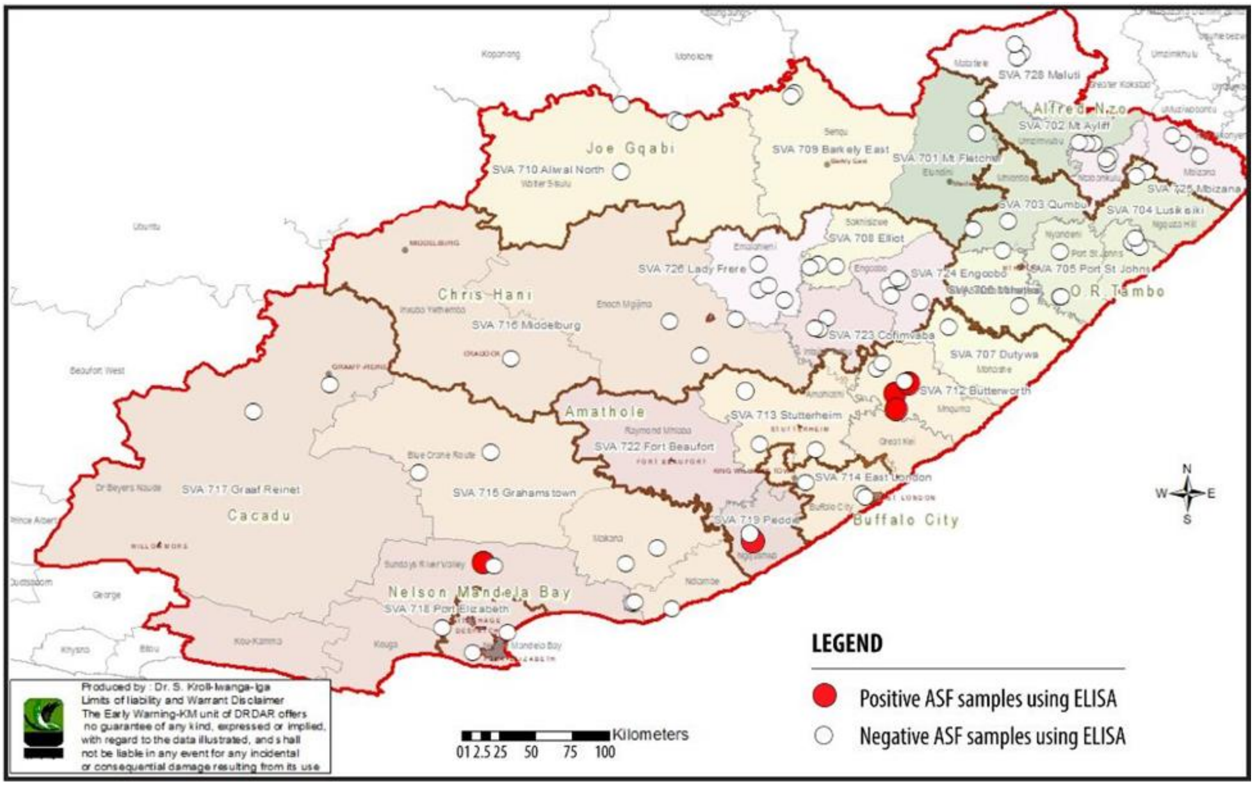

Figure 11:A map of Eastern Cape Province showing the negative and positive African swine fever samples using ELISA (August 2019 to May 2020).

4.4 Discussion

The number of female smallholder pig farmers was slightly higher (52%) than the number of males (48%). Although the difference between males and females was not statistically significant, the representation of female smallholder pig farmers reflects the cultural importance of this sub-sector in Xhosa culture, the most predominant in the province. Women in rural communities have an obligation to be involved in pig and poultry husbandry, while men manage other species (Batyi, unpublished data). Similar findings were noted in the rural pig and poultry sector of ECP where female smallholder farmers were more represented than males (Mtileni et al., 2013; Sithole et al., 2019; Simbizi et al., 2021), highlighting their socio-economic importance in providing the basic household needs (i.e., food, school fees etc.) (Alders and Pym, 2009). Among farmers interviewed, pensioners were more represented compared to young adults and adults, highlighting the importance of pigs as an additional income generating activity for this segment of the community. This is important for food security because of the virtual lack of welfare system in many African countries. A similar finding was noted in a recent survey of village chicken farmers in the province where pensioners were more represented in poultry farming than any other age category (Simbizi et al., 2021). Given the high unemployment rate in the province (Manyani et al., 2021), expansion of the smallholder pig industry could contribute to job creation and become a source of income for adults having difficulty finding permanent employment.

Smallholder pig farmers with only a primary school level of education made up the highest proportion of pig farmers (40.7 %) compared to those with secondary and tertiary education level. Similar findings were reported in other studies of the primary industry in the ECP where farmers with a low level of education were more represented (Mtileni et al., 2013; Katikati and Fourie, 2019; Simbizi et al., 2021). This could explain why farming in the ECP is still traditional and under developed despite the high number of livestock in the province (Katikati and Fourie, 2019). The level of a farmers' education is known to influence their scope of decision-making, and this is related to the success of a farming business (Lubambo, 2011).

The low level of education could also possibly explain the tendency to implement low biosecurity measures in this informal pig sector, because most pig farmers interviewed seemed not to be aware of the importance of biosecurity in preventing pig diseases, including ASF. Instead, they were relying on remedies to treat and prevent pig diseases. This finding was supported by similar studies done elsewhere, where farmers relied on the use of remedies instead of applying basic biosecurity measures to prevent pig diseases (Albernaz-Gonçalves et al., 2021; Poupaud et al., 2021; Mallioris et al., 2022). In this study, the most representative category of remedies used by smallholder pig farmers was antibiotics (31.1%), with tetracyclines and sulpha products being the most used remedies (Table 9). Tetracyclines were also reported to be the most used antibiotic in smallholder pig farming in Limpopo Province (Mokoele et al., 2014). The availability and use of these antibiotics by smallholder pig farmers coupled with a lack of knowledge and training on antibiotic use could contribute to antimicrobial resistance (AMR), which has become a public health concern in the last decades. The present study found that farmers had access to these antibiotics as over-the-counter medicines through local private livestock pharmaceutical companies. Antimicrobial use in both human and animals has been responsible for the emergence and spread of AMR in bacterial populations, resulting in increasing antimicrobial therapy failure (Mallioris et al., 2022). These findings highlight the need for a more detailed look at antibiotic use and possible links to AMR in these communities. A number of farmers did not report using any remedies to prevent or treat sick pigs (21.9%), which is probably a reflection of their socio-economic status. Traditional remedies also occupied an important place among remedies used by smallholder pig farmers (18.5%). A similar finding was noted in a study of village chickens where many farmers relied on traditional remedies to prevent and treat chicken diseases (Simbizi et al., 2021), with *Aloe ferox* Mill. *(Asphodelaceae)* or "ikhala" (in local language) being used in both chickens and pigs. Another frequently used remedy identified include macrocyclic lactones (antiparasitic), mainly used to treat skin disease (mange). The use of this group of remedy was found to be cost-effective in pigs in another study, since it could be used for both external and internal parasitic infestations (Laha, 2015).

In the present study, a free-ranging system was practiced by 8.4% of smallholder pig farmers, which still represents a high risk for ASF introduction and spread when there is an outbreak. About 72.4% of pig keepers interviewed confirmed the use of intensive production systems. However, the circulation of ASFV amongst confined domestic pigs in intensive production also occurs under conditions of low biosecurity that may include feeding of catering waste containing pig materials (Penrith, 2013). Furthermore, despite the confirmed use of an intensive system, it was found that many pigs were kept in very poor housing structures from where they could easily move in and out and wander around the village. Similar poor housing structure of pigs was also found in a study in Limpopo Province (Mokoele et al., 2014). In areas where a cycle between pigs and tampans (*Ornithodoros* sp.) exists, housing pigs in structures that offer a suitable habitat for the ticks was also reported to be an additional risk factor (Penrith et al., 2013). The lack of proper pig housing structures was therefore a limitation to the implementation of biosecurity for smallholder pig farmers in the province.

The high pig density in the ECP (STATS, 2016) with low biosecurity, facilitates increased movement and contact of pigs, particularly when there is informal trade in communal and peri-urban areas. This informal trade has been mentioned in previous studies as a major risk factor for ASFV transmission in domestic pigs (Costard et al., 2009; Brown et al., 2018; Beltran-Alcrudo et al., 2019; Penrith et al., 2019). A recent survey revealed that some backyard pig producers in the province were selling live pigs and pig products across the province without meat inspection or a health permit (informal market), (Simbizi et al., unpublished) and this was confirmed in the present study, thus contributing to the risk of disease spreading from smallholder farms. A segment of this informal market was reported to be more profitable than the formal one where pigs were sent to an abattoir for meat consumption (Simbizi et al., unpublished) providing less incentive for smallholders to send their meat to abattoirs where it can be inspected. The practice of informal slaughter lacks proper meat inspection to detect signs of ASF and other diseases, which could contribute to the transmission and maintenance of diseases in local pig populations (van Rensburg et al., 2020). This practice was also found to contribute to the propagation of *Taenia solium* cysticercosis, the causative agent of neurocysticercosis in the rural community of ECP (Sithole et al., 2019). Similarly, the impact of important neglected diseases like leptospirosis in rural communities of ECP is unknown because this communicable disease hasn't been investigated yet (Simbizi et al., 2022). A study on trading practices of pig farmers and movement of live pigs and their products in the ECP would give more insight into the epidemiology of pig diseases including ASF.

A high number of smallholder pig farmers (75.7%) used untreated kitchen waste (swill) when feeding their pigs. Feeding of swill containing pig remains has been proved to be a major risk to ASFV transmission in domestic pigs (Wang et al., 2019; Hu et al., 2021). The practice of swill feeding could be due to the lack of knowledge on the risks involved but is probably because these smallholder farmers could not afford using commercial feed alone. This finding was also reported in the Northern Cape and Free State Provinces where the practice of swill feeding was more likely due to the cost implications of obtaining commercial feed, especially when the costs in obtaining feed would most probably make the enterprise unprofitable within the available marketing options (van Rensburg et al., 2020). Farmers interviewed reported not using meat as part of swill, but this information could not be verified. Untreated kitchen or restaurant waste could contain meat products without a farmer's knowledge (van Rensburg et al., 2020). These risky practices could be reduced or eliminated by developing simple and cost-effective biosecurity measures and marketing opportunities that provide an incentive for investment and modernization of the pig industry (Penrith et al., 2019; Penrith et al., 2023).

The overall seroprevalence of ASF in the province was 0.01%, with the highest seroprevalence being in Amathole District, which had four positive samples originating from Mnquma municipality and one from the border with Great Kei municipality. Apart from Mnquma, where samples were collected in May 2020, the municipalities affected were sampled in 2019 and included pigs from Sunday's River Valley and Ngqushwa municipalities. This implies that an outbreak may have occurred in these pigs before May 2020 when the first outbreak was reported to the Department of Agriculture, Land Reform and Rural Development (DALRRD). These seropositive pigs could have survived virus infection without being detected, but this usually happens in areas where ASFV has long been present (endemic) (Beltran-Alcrudo et al., 2017) or in cases with low virulent ASFV exposure (Sun et al., 2021). Another explanation is that the positive ELISA samples were false positive results given the low prevalence and consequent low positive predictive value. However, the ELISA test had a high specificity and was repeated, making false positive results unlikely.

The DALRRD had earlier reported some ASFV sequences at about the same time the sampling for this study was concluding. Sequencing of ASFV from the ECP has revealed that genotype II, known to cause high mortality among susceptible pigs, was responsible for the May 2020 outbreaks in the province (DALRRD, 2021). Acute deaths could go undiagnosed and unreported in these smallholder communities, but data collected during the interviews and interaction between the research team and farmers during the sampling process suggest that there was no reported mortalities or dead pigs at the time of the sampling in the selected villages and surroundings. Hence, the significance of the ASF positive samples in our survey remains uncertain.

Ornithodoros Pavlovskyella ticks, which may be capable of transmitting ASFV have been found in the ECP in areas where warthogs are found (Craig et al., 2021a). These warthogs were widely translocated from the north to nature reserves and game ranches in the south, including ECP (Swanepoel et al., 2016). A small number of farmers (5.6%) confirmed that warthogs were seen in the vicinity of smallholder pig farms (Table 3) but this information could not be verified. Given the presence of tick vectors and warthogs, the combination poses a potential risk of ASF transmission. However, attempts to detect ASFV in both ticks and warthogs in the province have thus far yielded negative results (Craig et al., 2021b; Craig et al., 2022), making it difficult to confirm the existence of a sylvatic cycle. Hence, further research needs to be conducted in the ECP to conclusively confirm the ASF cycle present in the ECP. Nevertheless, farming systems that frequently involves free-ranging pigs, swill feeding and informal trading in communal and peri-urban areas were found in this study and these practices are known to contribute to the spread of ASF and similar diseases.

4.5 Conclusion

This is the first study describing the socio-demographics of smallholder pig farmers in the ECP and their practices related to the spread of ASF and other communicable pig diseases in the province. A low level of education for many farmers and reliance on remedies to treat and prevent pig diseases were the key findings that could explain the low level of implementation of biosecurity measures on their farms. Subsequently, smallholder pig farming in the province could be regarded as a potential risk for incursion and spread of pig diseases including ASF, posing a risk for commercial farms. Furthermore, the lack of knowledge and training on the use of antibiotics was another key finding that could result in incorrect use of these remedies, thus contributing to antimicrobial resistance in rural pigs. There is therefore a need to train smallholder pig farmers in biosecurity and antibiotic usage to improve disease control and prevent antimicrobial resistance.

This is also a first study that tried to estimate the seroprevalence of ASF in domestic pigs in the ECP using a WOAH-approved ELISA kit. Although the ASF determinants seem to be present in the province, further evidence is needed to confirm the existence of any ASF cycle. Nevertheless, farming systems that involve free-range pigs, swill feeding, and informal trade were identified as practices that could contribute to the spread of ASF and similar diseases in the province. This could be mitigated by developing simple and cost-effective biosecurity measures as well as marketing opportunities that provide an incentive for investment and modernization of the rural pig industry.

4.6 Limitations of the study

It was not always possible to get 15 smallholder pig farmers per local municipality on the day of interviews, hence the obtained number of 214 smallholder farmers interviewed instead of 250 farmers that were targeted in the study design. Also, due to constraints in manpower, the questionnaire survey did not take place at the same time as the serological survey. By the time the serological survey started, not every smallholder pig farmer interviewed still had the required number of pigs (at least 4 pigs) that included them in the survey. Some pigs were slaughtered or sold. To overcome this weakness, a few farmers in the vicinity of those interviewed had to be recruited to get the required number of pigs per village, hence the number of 239 farmers whose pigs were bled in this study. Finally, some farms surveyed had both chickens and pigs and this could be a confounder in terms of the study, but this was unlikely because similar poor biosecurity measures were observed for both chicken and pig farms.

4.7 Acknowledgement

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Ethical consideration

Permission to undertake this study was obtained from the Department of Agriculture, Land Reform and Rural Development (DALRRD) under section 20, the Directorate of Veterinary Services of the Department of Rural Development and Agrarian Reform (DRDAR), Eastern Cape Province and from the ethics committees of University of Pretoria (Faculty of humanities application ID: GW20180835HS; Faculty of Veterinary Science research committee application ID: REC109-18 and animal ethics committee application ID: V038-18).

Author contributions

VS designed the study, collected, and analysed data, and wrote the draft of the manuscript. RM had inputs on the introduction and discussion sections. JH conducted serology, data analysis and had inputs into the introduction, methodology and discussion. BG supervised the study design, data collection and analysis. He conducted detailed editing and had inputs on the introduction, methodology, discussion and conclusion sections.

Conflict of interest

The authors have no conflict of interest to declare.

Supplementary files

Appendix 12: Number of pigs sampled in each village per local municipality and per District during the survey in the Eastern Cape Province (August 2019-May 2020).

Appendix 13: Biosecurity measures recommended to prevent common transmission routes based on the authors' experience and knowledge of the disease transmission (Penrith et al., 2021)

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CHAPTER 5

USING VALUE CHAIN AND TRADE NETWORKS IN THE EASTERN CAPE PROVINCE OF SOUTH AFRICA, AS A BASIS FOR TARGETED RURAL CHICKEN SURVEILLANCE

Publication

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ABSTRACT

Despite the benefits of rural chickens in the Eastern Cape Province (ECP) of South Africa, this sector is still underdeveloped and poorly surveyed for poultry diseases. The lack of a sustainable poultry disease surveillance system coupled with communities and practices where the interactions between birds are high, emphasize the need for targeted surveillance of chicken diseases in the province. However, to set up such a system requires knowledge of the value chain and trade networks. Consequently, a survey, which involved a rural chicken value chain analysis that also included an assessment of trading practices to identify biosecurity hotspots and an identification of barriers to market entry for rural farmers was conducted. Secondly, a social network analysis of chicken movements in the province was carried out to identify trade hubs that could be targeted for disease surveillance based on their centrality within the network and their size and influence within their ego networks. Traders and their transport vehicles were identified as biosecurity hotspots that could be targeted for disease surveillance within the chain. Social network analysis identified three municipalities viz. Umzimvubu, King Sabata Dalindyebo (KSD) and Enoch Mgijima as trade hubs where interaction between rural chickens occurs and resources can be focused. The movement of spent hens from commercial operations that are transported over long distances and distributed in the rural areas and townships were a major risk for spread of poultry diseases. This is the first study to formally describe chicken trade networks within the province and the surrounding region. Its findings provide a model for cost effective targeted surveillance in the ECP and similar resource poor regions of the world. The study also provides insight into the profitability of rural chickens and a possible contribution to job creation and poverty alleviation once the barriers to market entry are lifted.

Keywords: disease surveillance, hotspots, value chain, rural chicken, trade networks, biosecurity.

5.1 Introduction

Livestock plays a major role in the social, cultural and economic environment in the Eastern Cape Province (ECP) of South Africa. The Eastern Cape is among the lowest commercial poultry producing provinces in South Africa with 6.5% of total production (SAPA, 2017). This production statistic, however, doesn't include the majority of rural chickens owned by many households in the province. The province has the highest number (31%) of agricultural households engaged in poultry farming (an average of 1 to 10 chickens per household) compared to other provinces in South Africa (STATS, 2016).

Rural chickens serve as the main source of protein, generate income through sales of eggs and birds; and play a significant role in sociocultural activities such as traditional ceremonies and rituals (Mtileni et al., 2009; Conan et al., 2012). Chickens are mainly managed by women and income from the chickens often pays for the education and nutrition of their children and households in general (Jensen and Dolberg, 2003).

In the Eastern Cape Province, similar to countries in Sub-Saharan Africa, infectious diseases constitute a major challenge to the growth and profitability of the rural poultry sector. A recent serological survey done in this province revealed a high prevalence of antibodies to H6N2 subtype avian influenza, avian infectious bronchitis and *Mycoplasma gallisepticum* (Simbizi et al., 2021). Due to limited resources, veterinary services rely on passive surveillance for the control of chicken infectious diseases in the village settings, which precludes early detection, or the prevention of disease spread. The reporting structure within veterinary services encompasses all the district municipalities and both surveillance and reporting systems are not risk-based. The lack of infrastructure that allows easy access to remote rural areas is also a constraint to effective disease control and surveillance. Consequently, animal movement control cannot be monitored and the risk of introducing new transboundary animal diseases is increased. Animal movements are key factors in disease transmission; thus by modifying the approach to conducting disease surveillance in the province, it is possible to steer the system towards risk-based surveillance, which refers to the use of concepts of risk in the design of surveillance programs such as a pig value chain analysis and trade network, prioritizing the populations that are most likely to be affected (Cameron, 2012).

Given their important societal value, rural chickens are moved extensively within villages and beyond via informal trade (McCarron et al., 2015). In most of the cases, this trade is facilitated by middlemen who buy chickens directly from commercial farms and resell them. Such movements are known to be accompanied by the spread of highly infectious diseases such as Newcastle disease and avian influenza (Meyer et al., 2017; Poolkhet et al., 2018; Guinat et al., 2020; Hautefeuille et al., 2020; Gierak et al., 2021).

The lack of a sustainable active poultry surveillance system coupled with communities and practices where poultry interactions are high, present an opportunity for targeted surveillance in resource-poor regions (Brioudes and Gummow, 2017). This involves placing surveillance systems in areas that are considered high-interaction areas or hot spots for livestock movement such as large markets with traders from many areas. Continuous assessment of the poultry disease situation in these foci could serve to monitor the disease status for the region. Timing this targeted surveillance with occasions associated with increased poultry movement, such as a holidays and cultural celebrations, would further increase the effectiveness of early disease detection (Brioudes and Gummow, 2017).

The knowledge of a rural poultry sector which includes its value chain can lead to a deeper understanding of the local trade and its practices, which can in turn assist in identifying high risk pathways that could be targeted for surveillance within the chain (Mubamba et al., 2018). Combining this information provides a basis for social network analysis (SNA) that could be used to plot the movement of poultry (Mubamba et al., 2018). In recent years, social network analysis has been increasingly used in veterinary epidemiology as a tool for disease management and risk-based surveillance (Dube et al., 2009; Frossling et al., 2012). Positional analysis of nodes within a network enables the selection of nodes for which the probability of an outbreak is the highest, and consequently where the surveillance should be focused. These potential super-spreader areas can thus be used for targeted surveillance (Rasamoelina-Andriamanivo et al., 2014).

However, despite the economic importance of chickens in the ECP, there are no published studies on rural chicken trade network and value chain in the province. The first objective of the study was therefore to identify biosecurity hotspots and chicken trade hubs that could be targeted for disease surveillance within rural ECP by combining value chain analysis and SNA. The second objective was to use the value chain analysis to identify the barriers to market entry for rural chicken farmers in the province.

5.2 Materials and Methods

5.2.1 Study design

5.2.1.1 General overview

An interview-based questionnaire survey targeting rural chicken farmers and other stakeholders involved in the rural chicken value chain (**Table 11**) in the ECP was conducted in two steps; from February to June 2019, an initial survey targeting chicken farmers was conducted, which was followed by a second survey from November 2020 to July 2021, based on information provided by chicken farmers in the first survey. The second survey targeted traders and processors identified by the farmers.

Table 11: Primary data sources for the survey conducted from February 2019 to July 2021 in the Eastern Cape Province

Main actors	Number of participants, and size of flock owned (range), as applicable	Gender	Towns/Municipality
Producers	210 farmers*	65 males 145 females	29 municipalities**
Traders	28	18 males 10 females	Mthatha, Queenstown, Mount Ayliff, King William’s Town, East London, Komga, Lady Frere, Gqeberha, Sterkspruit, Aliwal North, Mount Frere and Matatiele
Wholesalers	2	2 males	East London and Queenstown
Butcheries	8	8 males	Nelson Mandela, Emalahleni and Enoch Mgijima
Restaurants	38	38 females	Engcobo, Queenstown, Mthatha, Matatiele, Aliwal North, Sterkspruit, Mount Frere, Aberdeen, Grahamstown, Alexandria, Gqeberha and Kariega
Meat inspector	2	2 females	Enoch Mgijima

*****Average range of chickens kept by farmers: chicks: 1-500; pullets: 1-500; cockerels: 1-30; hens 1-550

******ECP municipalities except Raymond Mhlaba, Great Kie, Kouga and Kou-Kamma

Questionnaires that targeted each respective type of stakeholder were developed and administered by the research team. The questionnaires were based on those used in Eastern Zambia (Mubamba et al., 2018). Validation of the questionnaires was done through consultation with state veterinarians and animal health officials working in the areas being surveyed. The consultation with these officials involved feedback on the questions asked to check if they were understandable and relevant. These officials also had an opportunity to complete the questionnaires themselves and give feedback. The authors further validated the questionnaires by including questions that were common to all questionnaires and comparing them during the final analysis of data.

5.2.1.2 Study area

The study area was the whole of the ECP. The province has a population of 6,676,590 people (STATS, 2021), with a density of 39 people /km.[2] The main spoken language is Xhosa and the province is economically the poorest province in South Africa and has the highest unemployment rate in the country (Musemwa et al., 2013; Manyani et al., 2021). It therefore relies heavily on subsistence agriculture to support its economy. The informal poultry sector in the ECP is estimated to have 3,841,174 birds (STATS, 2016), most of which are found in the 6024 villages scattered throughout the province (Census, 2011).

ECP is divided into two metropolitan municipalities, viz. Buffalo City and Nelson Mandela Bay and six district municipalities. The district municipalities are in turn divided into thirty-one local municipalities. All thirty-one local municipalities and two metropolitan municipalities were included in the study.

5.2.1.3 Sampling procedure

A two-stage sampling strategy was used to calculate the required number of villages and households to be used in the study (Equation 1) (Thrusfield and Christley, 2018).

$$g=1.96^2\{(n-1)V_c+p_{exp}(1-p_{exp})\}/nd^2 \quad (1)$$

where *g* is the number of clusters (number of municipalities) to be sampled, *n* is the predicted average number of villages per municipality estimated at 100, p_{exp} is the expected prevalence or proportion of farmers that are involved in trade of poultry, which was estimated at 0.7 (Bongile Mlahlwa, Animal health technician, Chris Hani, personal communication, 2021), *d* is the desired precision at 0.1, and V_c is the between-cluster (municipality) variance estimated at 0.02 for the first stage. A low between-cluster variance of 0.02 was assumed because the population structure in most rural communities is generally similar (Mubamba et al., 2018).

Equation (1) was used again to calculate a sample size of three villages per selected municipality where *n* (the predicted average number of households per village), V_c (the between-village variance), p_{exp} (the prevalence of poultry movement among households) and *d* were 100, 0.02, 0.7 and 0.1, respectively. Consequently, a total number of 99 villages covering the entire province was calculated. Since the study design included a pig survey (data to be published elsewhere), a list of farmers with at least four chickens and four pigs was generated with the help of the extension officers and a sample of five households per selected village was randomly selected giving a total number of 15 households (or 15 farmers) per local municipality. The total number of households was therefore 495, which was rounded to 500 households and divided into 250 chicken farmers and 250 pig farmers.

An interview-based questionnaire of households with chickens was administered by the research team with the assistance of veterinary and extension services from the Department of Rural Development and Agrarian Reform, Eastern Cape Province.

For SNA and value chain purposes, an attempt to identify all chicken traders, middlemen, and processors (e.g., restaurants) was made through follow up from chicken farmers' interviews and the existing number of chicken traders at the major towns in the province. Additional information was obtained from wholesalers, butcheries, restaurants, and meat inspectors (**Table 11**).

5.2.2. Study procedures and data analysis

5.2.2.1 Interviews

An information sheet and consent form were provided to respondents prior to the commencement of interviews, and the participants were required to sign a consent form acknowledging that they had read and understood the documents.

The questionnaire comprised different sections, namely general information, such as farm structure and flock size, types/sources of inputs (feed, water, day-old chicks used on the farm), data on the movement of live chickens and chicken products, trading practices, existing regulations of chicken trade, and finally animal health management and waste disposal.

5.2.2.2 Data management and analysis

The questionnaires were recreated and stored in Epi Info®. All the data obtained from the interviews were then entered and stored in Epi Info as database files. During analysis, the tables required for analysis were exported to Excel, where they were merged, sorted and edited, after which they were exported to the appropriate software package for analysis. To maintain confidentiality, all the data were treated anonymously.

Value chain analysis

For the purpose of this study, descriptive data analysis was used to characterize the value chain of rural chickens in the ECP. The data collected was analysed to identify the main actors and to characterize the key structure or elements of the value chain. Quantitative and qualitative data collected from key informants were also analysed to assess the costs and calculate the net profit margin in the value chain. A descriptive analytical narrative was used to present the findings from the study in order to have a comprehensive picture of the key issues concerning the value chain of rural chickens in the province.

Identification of biosecurity hotspots within the value chain

Biosecurity hotspots in the value chain were identified by assessing the practices of the chicken trade in the ECP using information provided by rural chicken farmers and traders in the questionnaire survey. This research used similar methodologies from other studies (Kerkhove et al., 2009; McCarron et al., 2015; Brioudes and Gummow, 2016; Mubamba et al., 2018) to identify the biosecurity hotspots within the value chain.

Mapping of the chicken value chain in the Eastern Cape Province

The mapping part of the study involved the creation of profiles (i.e., diagram representing people, flows of animals and products etc.) for the key components of the rural chicken system. For each profile, relevant data from the interviews were analysed and combined to create a detailed profile map**.** The main actors in the chains were identified and linked graphically by arrows to represent flows of people, animals and products. Other data regarding interactions present within the chains was kept for the narrative explanation.

Identification of barriers to market entry for rural farmers using the value chain analysis

Data from the questionnaire interviews were combined and analysed to determine the barriers to market entry for rural chicken farmers. The identified barriers were grouped into different categories as described in the Pro-Poor Livestock Policy Initiative manual (Ramsay and Morgan, 2009).

5.2.3 Social Network Analysis

5.2.3.1 Conversion of cross-sectional data to social network dat**a**

Data on the movement of live chickens and related products obtained through farmers and traders (combined) interviews were exported from Epi Info to Excel for merging and editing. Each unique destination of chicken and its matching origin were entered under two columns (origin and destination) in the spreadsheet. These data were formatted as nodelists (a format which is used only for binary data with no tie strengths) in the software program Ucinet® (Borgatti et al., 2002). The municipalities were assigned as nodes whereas the movement of chickens and downstream products between these nodes was assigned as ties (Hanneman and Riddle, 2005; Borgatti et al., 2018). These ties had no direction (undirected network).

5.2.3.2 Network visualization

The live poultry and product network was visualized as one network using Net Draw®, a software program embedded within Ucinet® (Borgatti et al., 2002; Hanneman and Riddle, 2005). The sociograms created were then edited and saved as jpeg files.

5.2.3.3 Centrality

Betweenness centrality of each node in the whole network (defined as a measure of how often a given node falls along the shortest path between two other nodes) was calculated using the Freeman betweenness centrality method in Ucinet® (Borgatti et al., 2018). High betweenness nodes were identified as central nodes (chicken trade hubs) based on their potential for controlling flows through the network.

5.2.3.4 Ego network analysis

A personal-network research design was used, where an ego network is first obtained by sampling a population to obtain a set of respondents (egos) and then a list of people (alters) the egos are connected to is collected for each ego, along with the nature of the ties connecting them to the ego, characteristics of the alters, and the respondent's perceptions of the ties among the alters. Data obtained for this ego network design are therefore ego-alter ties (Borgatti et al., 2018). An ego network analysis was therefore conducted by assessing the density measures of each ego in its neighbourhood. In this study, "ego" was an individual "focal" node (municipality). It consists of the ego, the node/s that the ego is connected to (referred to as ego's alters), and the ties between ego's alters (Borgatti et al., 2018). As mentioned above, the type of ego neighbourhood was undirected. Density measures assessed, included size, number of directed ties, brokerage and betweenness of each ego. Egos with the largest networks, normalized brokerage and betweenness were identified as being powerful and central. The following are brief descriptions of these measures as outlined by Hanneman & Riddle (2005) and Borgatti et al., (2018) (**Table 12**).

Table 12: Descriptions of the social network measures used in the study according to Hanneman & Riddle (2005) and Borgatti et al., (2018).

Network parameter	Definition
The size of the ego network	Number of nodes that included one-step out neighbours of the ego, plus the ego itself.
The number of directed ties	Number of connections among all nodes in the ego network.
The number of ordered pairs	Number of possible directed ties in each ego network.
The density	Number of ties divided by the number of pairs, representing the percentage of all possible ties in each ego network.
Brokerage	Function associated with having structural holes (a structural hole is the

	lack of a tie between two alters within an ego network).
Normalized brokerage	Brokerage divided by the number of pairs: It assesses the extent to which the ego's role was that of the broker.
Betweenness	It is when the ego is between two other actors if it lies on the shortest directed path from one to the other.
The ego betweenness	Indexes the percentage of all geodesic paths from neighbour to neighbour that passes through the ego.
Normalized betweenness	Compares the actual betweenness of the ego to the maximum possible betweenness in the neighbourhood of the size and connectivity of egos.
The network centralization index	It is calculated as the sum of differences between the centrality of the most central node and the centrality of every other node, divided by the maximum possible

5.2.3.5 Identification of chicken trade hubs

Nodes (municipalities) that were most centrally located in the whole network analysis (using Freeman betweenness centrality) and identified as influential egos according to the size, normalized brokerage and normalized betweenness in the ego networks analysis were identified as important chicken trade hubs that could be targeted for disease surveillance.

5.3 Results

5.3.1 General information

The number of farmers, traders, processors and other key-informants interviewed is provided in **Table 11**. Among 210 farmers interviewed, females were more represented (69 %) than males (31 %).

5.3.2 Description of chicken farmers (producers)

Indigenous breeds were generally scavenging for food around the yard or village during the day and kept in poultry houses at night, with occasional or no supplementation. Other breeds (layers and broilers) were kept in a confined area and fed on commercial feed. This feed was produced by specialized companies in South Africa. The majority of farmers acquired one day old chicks through breeding of the indigenous chickens or from commercial hatcheries (layers and broilers). Occasionally commercial hatcheries used traders to supply these chicks. Extension services occasionally supported the households with small poultry projects by contracting a service provider to supply these chicks. The study found another category of traders within the community who owned incubators to produce one day old chicks.

A total of 210 farmers were interviewed. Among these, 68 farmers (32.4%) were not frequently selling their chickens or chicken products. Farmers involved in selling of their chickens and chicken products on a regular basis (every month) were 32 (15.2%) whereas the majority of farmers were not selling at all (52.4%) (Appendix 14).

5.3.3 Actors in the value chain and identification of biosecurity hotspots.

The following actors in the chain were identified: producers (farmers), traders, processors (restaurants) and consumers (**Figure 12**). For most of the farmers (78%), chicken farming was contributing a small percentage (an average of 30%) of their total monthly income once they had deducted the cost of production. Only 2% of farmers confirmed that their activity contributed above 50% to the total monthly income. By calculating the net profit margin, the following categories in the value chain were found to add value to the selling activity of chickens and chicken products: farmers (producers) who sell eggs from commercial layer breeds (Appendix 15), those selling live spent hens, processors (restaurants) (Appendix 16) and traders who sell day old chicks hatched from individual incubators (Appendix 17). Traders with trucks were buying live spent hens from the farm gate or depots at the average cost of R35 and were selling them to other small traders and restaurants at the average cost of R90. These small traders were in turn selling their chickens directly to the consumers or restaurants at the average cost of R120. The majority of farmers confirmed they sold more chickens and their products in winter (from May to July) and during the festive season (from November to January). However, for traders, there was no specific period with increased sales (year-around sales). Traders along with their vehicles used to transport chickens were therefore identified as biosecurity hotspots that could be targeted for disease surveillance.

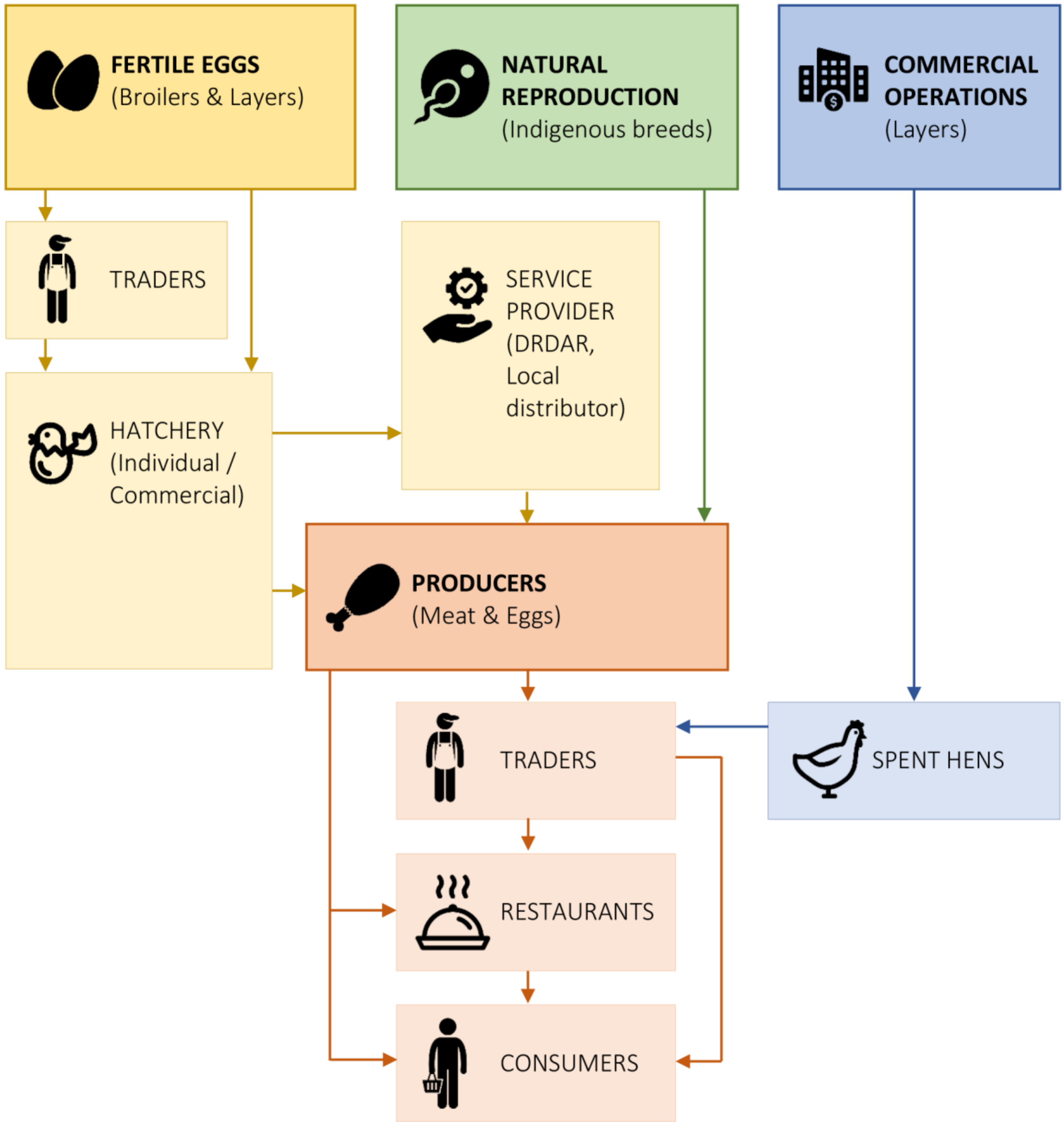

Figure 12: Mapping of rural chicken value chain in the Eastern Cape Province, 2021

5.3.4 Identification of barriers to market entry for rural farmers

The following categories were identified as the main barriers to market entry for rural farmers after analysis of the questionnaire data: production barriers, product barriers, social barriers, trading barriers and policy as a barrier (**Table 13**).

Table 13: Classification of barriers to market entry for ECP rural chicken farmers according to the survey done from February to June 2019

Category	Example of specific barriers
1. Production barriers	Access to means of production
	Knowledge of how to produce
	Knowledge of when to supply
	Knowledge of cost of production
	Risk in production cycle
	Quality of product available for sale
2. Product barriers	Perishability of product (chicken meat)
3. Social barriers	Nature of personal relationships (between markets and producers)
4.Trading barriers	Culturally production system not aligned to the market system
5. Policy as a barrier: advantages given to large scale commercial producers (through policy)	Subsidised loans, Import from high chicken meat producing countries,

5.3.5 SNA of live chicken movement and products in the province

A total of 83.8% (176 from 210 farmers interviewed) reported details of destinations and origins of chickens and chicken products in the previous year, while 75% of traders (21 out of 28 traders interviewed) provided these details.

5.3.5.1 Network visualization

A total of 35 nodes were identified in the network for chickens and chicken products (**Figure 13**). The nodes representing Eastern Cape municipalities tallied 27 whereas 8 nodes fell outside the province. These included municipalities from the Free State, KwaZulu-Natal, and Gauteng Provinces and one node represented the Republic of Lesotho. All of these nodes were identified by respondents as either destinations or origins of their chicken or chicken products.

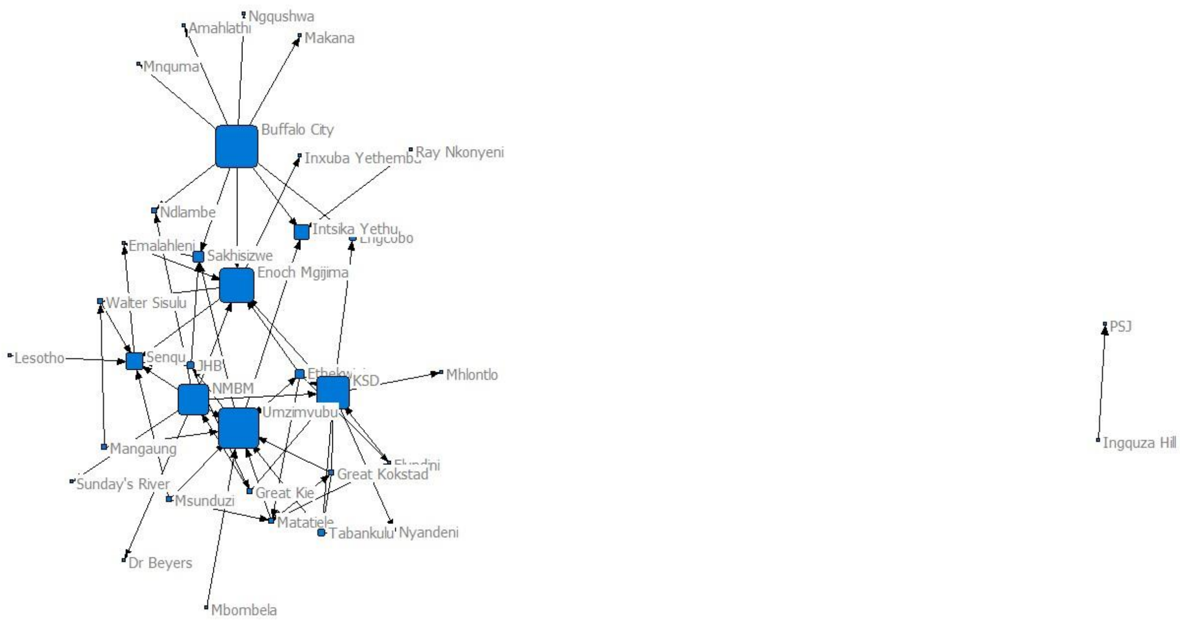

Figure 13: Network visualization for live chicken movement and chicken products in the Eastern Cape Province according to the data provided by rural chicken farmers and traders during the survey conducted from February 2019 to July 2021 (Source: Ucinet®)

5.3.5.2 Centrality measure

Betweenness centrality results demonstrated that Umzimvubu lay along every shortest path between every pair of other nodes; therefore, it was more central and powerful with a normalized betweenness value of 20.48, followed by KSD with a normalized betweenness value of 15.47 and Enoch Mgijima (normalized betweenness value of 13.43). The overall network centralization index was 18.03%.

5.3.5.3 Ego network analysis

The results of the ego network analysis are shown in **Table 14**. The larger ego networks had the highest normalized brokerage and ego betweenness. A higher normalized brokerage implies that a high number of altars depends on the ego for a connection, while higher normalized ego betweenness indicates how central the egos are in their network. Thus, normalized brokerage and normalized ego betweenness indicate how powerful and central a municipality is within its neighbourhood.

Table 14: Ego network density measures of annual chicken movements and products within ten Eastern Cape municipalities according to data provided by farmers and traders during the survey conducted from February 2019 to July 2021

Ego (Municipality)	Size	Ties (directed)	Pairs	Density	N. brokerage	N. betweenness
Umzimvubu	11	6	110	5.45	0.95	40.45
KSD	10	6	90	6.67	0.93	27.78
Buffalo City	9	0	72	0	1	0
E. Mgijima	8	5	56	8.93	0.91	43.75
NMB	8	4	56	7.14	0.93	9.82
Senqu	7	4	42	9.52	0.90	27.38
Matatiele	5	5	20	25	0.75	25
Tabankulu	4	3	12	25	0.75	20.83
Elundini	3	2	6	33.33	0.67	16.67
Emalahleni	3	1	6	16.67	0.83	50

5.3.5.4 Identification of chicken trade hubs

Based on centrality within the network, size, high brokerage and betweenness within their ego networks (**Table 14**), Umzimvubu, KSD and Enoch Mgijima were identified as important chicken trade hubs of Eastern Cape Province. These hubs could be targeted for disease surveillance.

5.4 Discussion

The findings from this study revealed that the majority of rural chicken farmers kept a small number of chickens (1-500) of mixed types (indigenous, layers and broilers chickens), which was consistent with the previous published data on the agricultural households engaged in poultry farming in South Africa (STATS, 2016). The production of meat and eggs were found to be very low (Appendix 14) for the majority of farmers, leading to low and irregular sales. The analysis of the value chain identified the main actors, namely producers (farmers), traders and processors (restaurants). These actors did not necessarily belong to the same community. Some actors like traders connected different communities through the sales of chickens and related products. The absence of retailers and wholesalers in the chain could be explained by many factors described as barriers to market entry (**Table 13**). The main barrier was production which involved basic knowledge from farmers (**Table 13**). The lack of knowledge among the majority of farmers was found to be linked to their low level of education (Nyoni and Masika, 2012; Idowu et al., 2018; Simbizi et al., 2021). Furthermore, as one of the poorest provinces in the country, the ECP has many people relying on social grant and pension money for survival. This makes it difficult for local producers who have to sell their chickens or chicken products on credit. The majority of farmers preferred selling live chickens but the study found a small proportion of farmers who preferred slaughtering and selling chicken meat. The existence of an informal (live sales) value chain in the rural sector of ECP was also consistent with the findings from another study in the country (Louw et al., 2017) and this could be regarded as a public health issue since there is no meat inspection done and zoonotic diseases like salmonellosis could be transmitted. The local abattoirs in the province don't slaughter rural chickens as these birds don't meet their requirements. The majority of farmers were trading within their communities only and directly to consumers which reduced the risk of diseases spreading. This finding is similar to that reported in Pacific Islands (Brioudes and Gummow, 2017).

The dominance of the domestic market by large import volumes of broiler meat from northern hemisphere countries and Brazil is another factor that cannot be ignored; therefore, policy is a barrier. South Africa's performance is comparable to these countries in terms of technical efficiency, but local producers incur losses once input costs are considered. One of the key drivers of higher production costs in South Africa, compared to Brazil and the USA, is that South Africa imports approximately 90% of its soybean meal requirements (Davids, 2013). Involving the youth and providing enough training in poultry farming to increase production could be regarded as one of the recommendations to create jobs and alleviate the poverty. The policy makers also have a role to play in providing local producers access to loans, abattoirs, and markets.

The movement of live chickens in the province was dominated by spent layers. Although these birds originate from commercial farms, they were included in the study since they most frequently ended up in the rural sector once their production cycle had come to an end. This survey confirmed the findings of previous studies (Abolnik, 2017) that the traders moved larger flocks using trucks and travelled over long distances (i.e., from KwaZulu-Natal to ECP) to supply birds to informal markets, including townships and rural areas, and the average cost of a spent hen layer was R35. The study could not identify middlemen who usually play an important role in disease transmission in other countries (Van Kerkhove et al., 2009; McCarron et al., 2015; Sealy et al., 2019). Middlemen might have been missed due to possible bias in sampling and selection of respondents (Mubamba et al., 2018). Unlike in Zambia where winter and festive season were the targeted periods with increased sales (Mubamba et al., 2018) , there was no specific season that could be targeted for disease surveillance in the current study, since the main trade was dominated by spent hens which are sold year-around.

The centrality of each municipality (node) involved in the study was assessed using the Freeman betweenness centrality method defined as a measure of how often a given node falls along the shortest path between two other nodes. Thus, if disease surveillance was placed at Umzimvubu, KSD and Enoch Mgijima (high betweenness nodes), the probability for early detection of any outbreak and its control would be high since these two municipalities have the potential for controlling flows through the network (**Figure 13**).

The ego networks analysis further revealed that municipalities with large networks and high brokerage are centrally located within their ego networks as targets for disease surveillance. The assumption made for measuring the brokerage within an ego network is that unconnected alters are more likely to offer ego more benefits and influence its effective size (Burt, 1995). Theoretically, if a disease outbreak occurred within the neighbourhood, the probability of detecting it within that neighbourhood before it spreads further is higher because most municipalities within the neighbourhood are not connected to each other but directly to a municipality in focus. Similarly, any disease outbreak inside the focal node would trigger a rapid response since the connected nodes to that focal node would be aware of it in advance. The municipalities with large networks and high brokerage (Umzimvubu KSD and Enoch Mgijima) were found in the densely populated areas, like Kenya and Zambia (McCarron et al., 2015; Mubamba et al., 2018). Buffalo City could have taken the third place after KSD, but this was affected by the lack of directed ties (**Table 14**). The results identified a movement of chickens and related products from the Republic of Lesotho into other nodes closer to the identified trade hubs (Umzimvubu and Enoch Mgijima), implying that active surveillance around Senqu, Nelson Mandela Bay, Walter Sisulu and Emalahleni would be also important to prevent any disease spread from the Republic of Lesotho (**Figure 13**).

The study also demonstrated the potential growth of local producers through expanding local egg producers, traders owning their own incubators and access to processors (restaurants). Although some parameters like fixed costs were not considered in this study, the data showed that the rural chicken sector is likely to be profitable, hence sustaining livelihood and food security as demonstrated by Jensen and Dolberg (2003).

The spent hens were the only chicken meat found in the surveyed restaurants because consumers considered them to be tastier. This is in agreement with another study done in South Africa (Abolnik, 2017). Although a few producers, traders and processors knew about the requirement for a health permit for selling chickens and chicken products, no one could present such a permit during the interview. Making traders aware of the importance of having permits would have a positive impact on chicken disease surveillance and follow up during outbreaks. Promoting the rural layer chicken farmers would benefit both farmers and processors based on the calculated net profit margin and this is supported by the fact that in South Africa, a layer hen still has a value at the end of its production life (SAPA, 2020).

5.5 Conclusion

This is the first study describing chicken movement networks in the Eastern Cape Province and surrounding regions. The findings provide insights into coordinating a targeted surveillance in the province that could be extended to other provinces and resource poor countries, if deemed to be feasible. Targeted surveillance is a relatively cost-effective option for disease surveillance since it focuses primarily on hotspot areas where a high risk of disease transmission exists thus allowing better and more efficient use of existing resources. The study also provides useful information on the value chain that could be used by policy makers and other stakeholders such as veterinary services. Finally, it provides a better understanding of some of the barriers to market entry for rural farmers that could be addressed by the provincial authorities to sustain and expand rural poultry farming in the ECP. Implementation of these measures could provide job creation and poverty alleviation.

Conflict of interest

The authors have no conflict of interest to declare.

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CHAPTER 6

RATIONALIZING RESOURCES THROUGH TARGETED ACTIVE SURVEILLANCE OF SMALLHOLDER PIG FARMERS IN THE EASTERN CAPE PROVINCE OF SOUTH AFRICA

To be submitted for publication

ABSTRACT

Pig farming in the rural Eastern Cape Province (ECP) of South Africa represents an important economic sector and contributes to food security. Infectious diseases and insufficient veterinary resources threaten the food security contribution from this sector. Due to a lack of effective disease surveillance system in the province, a new targeted surveillance approach is needed to ensure food security. Consequently, a survey, which involved an analysis of smallholder pig value chain, but also included an assessment of trading practices to identify biosecurity hotspots was conducted. Secondly, a social network analysis (SNA) of pig movements was carried out to identify trade hubs that could be targeted for disease surveillance.

The smallholder sector was dominated by pigs and pig products from rural settings that could be traded between municipalities, mainly in winter and festive season, often without meat inspection, a permit or a health certificate, posing a risk for the spread and propagation of diseases. These trade practices, coupled with low level of biosecurity measures application in farms, were traced to backyard pig producers, making them biosecurity hotspots within the chain. Three municipalities were identified by SNA as trade hubs. With a critical shortage of resources within veterinary services, the results showed that active surveillance of backyard pig producers in these hubs could result in more rapid detection of disease outbreaks and a quick response using the same available capacity. The benefits of using this approach to enhance food security are discussed and represent a novel approach for controlling pig diseases and increasing food security in resource-poor countries. Our findings advocate a new risk-based surveillance system and an improved reporting system within veterinary services based on targeted surveillance that provides more efficient use of available resources.

Keywords: targeted surveillance, biosecurity hotspots, smallholder pig value chain, trade networks, food security

6.1 Introduction

In many African countries, the need for cheap sources of protein has encouraged the growth of commercial pig farming (Penrith, 2013). However, the commercial pig sector in the Eastern Cape Province (ECP) of South Africa is relatively small and only produces 6% of the total production countrywide, leaving the huge balance to the smallholder sector (DAFF, 2018). Thus the majority of the pigs are kept by smallholders in backyards or in traditional free ranging systems similar to other parts of Africa (Wilson and Swai, 2014). The ECP has the highest number (69.4%) of agricultural households engaged in pig farming with an average of 1 to 10 pigs per household compared to other provinces in South Africa (STATS, 2016). This informal pig sector is of socio-economic and cultural importance and is considered as one of the most important sources of income that ensures food security for many households. Its contribution to the national production and Gross Domestic Product (GDP) still needs to be determined comprehensively. Despite its importance, this subsector is still vulnerable to many challenges, including highly infectious diseases which have a negative economic impact on many households. The eradication of the last outbreak of Classical swine fever in the province was achieved by a massive stamping-out campaign with nearly half a million pigs being culled (Akol and Lubisi, 2010). From 2020, the ECP experienced outbreaks of African swine fever in domestic pigs which spread across the ECP municipalities (DALRRD, 2022). The causal agents of these outbreaks can be maintained through uncontrolled spread of the pathogen in populations of domestic pigs, which in small scale pig farming, involves the utilization of poor husbandry practices and informal trading in communal and peri-urban areas (Penrith et al., 2019).

A sustained control of these diseases can be achieved by reducing the risks of disease transmission in the pig population, in addition to early disease detection, containment and response. To reduce the risks, an understanding of the risks and the factors that determine them is required (risk analysis). Detailed knowledge about the smallholder pig sector and the behaviour or practices of the people involved in all stages of this sector and marketing is an essential component of risk analysis. This knowledge can be developed and enhanced through value chain analysis (FAO, 2011).

In addition, the social network analysis has been progressively used in veterinary epidemiology as a tool for disease management and risk-based surveillance (Dube et al., 2009; Frossling et al., 2012; Acosta et al., 2022). Positional analysis of nodes within a network enables the selection of nodes for which the probability of an outbreak is the highest, and consequently where the surveillance should be focused. These potential super-spreader nodes can thus be used for targeted surveillance (Rasamoelina-Andriamanivo et al., 2014; Brioudes and Gummow, 2016; Mubamba et al., 2018).

Disease surveillance in the rural sector of ECP is poor due to a lack of resources (human and financial) and relies primarily on passive surveillance. The reporting structure within veterinary services encompasses all the district municipalities and both surveillance and reporting systems are not risk-based. The lack of infrastructure that allows easy access to remote rural areas is also a constraint to effective disease control and surveillance. Consequently, animal movement control cannot be monitored and the risk of introducing new transboundary animal diseases is increased. Animal movements are key factors in disease transmission; thus by modifying the approach to conducting disease surveillance in the province, it is possible to steer the system towards risk-based surveillance, which refers to the use of concepts of risk in the design of surveillance programs such as a pig value chain analysis and trade network, prioritizing the populations that are most likely to be affected (Cameron, 2012).

The objective of this study was therefore to analyse the smallholder pig value chain and movement of pigs and pig products for informing targeted surveillance in the rural ECP; to better utilise the resources available and provide a cost-effective active surveillance system that promotes early detection of diseases, reduced mortalities and increased production.

6.2 Materials and Methods

6.2.1 Study design

6.2.1.1 General overview

An interview-based questionnaire survey targeting smallholder pig farmers and other participants involved in the smallholder pig value chain (**Table 15**) in the ECP was conducted in two stages; from February to June 2019, an initial survey targeting pig farmers was conducted, which was followed by a second survey from November 2020 to July 2021, based on information provided by pig farmers in the first survey. The second survey targeted abattoirs, meat traders, butcheries, supermarkets, and pig processors identified by the farmers.

Questionnaires for each respective type of participant were developed and administered by the research team. The questionnaires were based on those used in Eastern Zambia for social network analysis (Mubamba et al., 2018) and their validation was done using a similar methodology as described in another study done on the chicken trade networks and value chain analysis in the Eastern Cape Province (Simbizi et al., 2022).

Table 15: Participants interviewed during the survey conducted from February 2019 to July 2021 in the Eastern Cape Province

Main actors	Number of participants, and size of flock owned (range), as applicable	Gender	Towns/Municipality
Producers	214 farmers*	103 males 111 females	29 municipalities**
Abattoirs	5	5 males	Queenstown, Uitenhage, Gqeberha, Elliot
Supermarkets	13	12 males 1 female	Lady Frere, Queenstown, Elliot, Aliwal North, Graaf Reinet, Cradock, Matatiele, Kirkwood and Mthatha
Butcheries	10	9 males 1 female	Queenstown, Aliwal North, Sterkspruit, Matatiele, Mthatha, Uitenhage, Kirkwood and Gqeberha
Tshisanyama (pubs)	16	13 males 3 females	Lady Frere, Queenstown, Mthatha, Matatiele, Aliwal North, Sterkspruit, Aberdeen, Grahamstown, Gqeberha, East London, Whittlesea, Elliot
Street vendors	22	3 females 19 males	Lady Frere, Queenstown, Matatiele, Aliwal North, Sterkspruit, Grahamstown, Gqeberha, East London, Mount Aylif, Butterworth, Kirkwood

*Range of pigs kept: piglets: 1 - 65; gilts: 1 - 37; sows: 1 - 81; boars: 1 - 46

**ECP municipalities except Raymond Mhlaba, Great Kei, Kouga and Kou-Kamma

6.2.1.2 Study area

The study area was the whole of the ECP. The province has a population of 6,676,590 people (STATS, 2021), with a density of 39 people /km². ECP is economically the poorest province in South Africa and has the highest unemployment rate in the country (Manyani et al., 2021). The informal pig sector in the ECP is estimated to have 536,108 pigs (STATS, 2016), most of which are found in the 6024 villages scattered throughout the province (Census, 2011). The province is divided into two metropolitan municipalities and six district municipalities. The district municipalities are in turn divided into thirty-one local municipalities. All thirty-one local municipalities and two metropolitan municipalities were included in the study.

6.2.1.3 Sampling procedure

A two-stage sampling strategy was used to calculate the required number of villages and households to be used in the study (Thrusfield and Christley, 2018). The study design included a chicken survey conducted in the province, hence the sampling procedure and questionnaire interviews used the same study design described and published in a parallel study on chicken trade networks and value chain analysis in the Eastern Cape Province (Simbizi et al., 2022). The calculated number of households to be surveyed in the study was 495, which was rounded to 500 households and divided into 250 chicken farmers and 250 pig farmers (Simbizi et al., 2022).

For SNA and value chain purposes, an attempt to identify all pig traders and processors (e.g., restaurants) was made through follow up from pig farmers' interviews and the existing number of pig traders at the major towns in the province. Additional information was obtained from wholesalers, butcheries, restaurants, and meat inspectors (**Table 15**).

6**.**2.2. Study procedures and data analysis

6.2.2.1 Interviews

Before the interviews, participants were required to sign a consent form. An information sheet was also provided to them, explaining the aim of the project. The questionnaire comprised different sections, namely general information, such as farm structure and flock size, types/sources of inputs, data on the movement of live pigs and pig products, trading practices, existing regulations of trade, and finally animal health management and waste disposal.

6.2.2.2 Data management and analysis

Epi Info® was used to store all the recreated data obtained from the interviews. Excel® was used to merge, to sort and to edit the tables before the final analysis. All the data were treated anonymously.

6.2.2.2.1 Value chain analysis

For this study, descriptive data analysis was used to characterize the value chain of smallholder pig farming in the ECP. The questionnaire data were analysed to identify the main actors and to characterize the key structure or elements of the value chain (Simbizi et al., 2022). Detailed information regarding the trading practices (frequency of selling, number of live pigs or quantity of pig products sold over the past twelve months, number of farmers actively involved in trade of live pigs or pig products etc.) was combined and analysed to understand the role played by smallholder pig farmers in the value chain (Appendix 18). Quantitative and qualitative data collected from key informants were also analysed to assess the costs and to calculate the net profit margin. The net profit margin which measures how much net income or profit is generated as a percentage of revenue was calculated for each pig sold (or pig meat) per category of actors. For instance, for backyard pig producers involved in pig clubs or "umbuto", the net profit margin was calculated for each of the four farmers interviewed (Appendix 19). For meat traders, the net profit per pig sold was calculated for each of the three meat traders interviewed during the study (Appendix 20). For supermarkets and butcheries, the net profit margin was calculated for twenty-three supermarket and butchery owners interviewed and an average buying and selling price per kg of meat was used in the calculation (Appendix 21). For processors (restaurants, tshisanyama or grills), the net profit margin was calculated for sixteen processors interviewed and an average buying price (from abattoir or from informal market) and selling price per kg of meat was used in the calculation (Appendix 22). A descriptive analytical narrative presenting the findings was used to interpret the main issues related to the value chain in smallholder pig farming (Simbizi et al., 2022).

6.2.2.2.2 Identification of biosecurity hotspots within the value chain

Biosecurity hotspots in the value chain were identified by assessing the practices of the pig trade in the ECP using information provided by smallholder pig farmers and other actors identified in the chain. The method used to identify biosecurity hotspot was similar to the one described in “a value chain approach to animal diseases risk management” where a socio-economic analysis of the value chain was used in risk analysis (FAO, 2011). This included an understanding of what the stakeholders had at stake (margins made at different stages, value added, seasonality of trade, and extra requirements i.e., biosecurity measures).

Mapping of pig value chain in the Eastern Cape Province

The mapping part of the study used the same methodology as described previously in a study on chicken trade networks and value chain in the ECP (Simbizi et al., 2022).

6.2.2.2.3 Reporting structure

The veterinary reporting structure within the Eastern Cape Province was examined to identify where more efficient use of existing resources could be utilized for the purpose of disease surveillance of smallholder pig farms. The information on the existing veterinary reporting structure was obtained from the Directorate of Veterinary Services in the Eastern Cape Province (Sabine Lwanga, Provincial Veterinary Officer, DRDAR, personal communication, 2022). Other sources used were Animal Disease Act (Act 35 of 1984) and Meat Safety Act (Act 40 of 2000).

6.2.2.2.4 Social Network Analysis

6.2.2.2.4.1 Conversion of questionnaire data to social network data

The conversion of data from the questionnaire interviews was done in a similar manner as described by Simbizi et al. (2022) for the published article on chicken trade network study. Data were analyzed as nodelists format (a format which is used only for binary data with no tie strengths) in the software program Ucinet® (Borgatti et al., 2002). The municipalities were assigned as nodes whereas the movement of pigs and downstream products between these nodes was assigned as ties without direction (Hanneman and Riddle, 2005; Borgatti et al., 2018).

6.2.2.2.4.2 Network visualization

The live pig and product network was visualized as one network using Net Draw®, a software program embedded within Ucinet® (Hanneman and Riddle, 2005).

6.2.2.2.4.3 Centrality

Betweenness centrality of each node in the whole network was calculated using the Freeman betweenness centrality method in Ucinet® (Borgatti et al., 2018). The central nodes or pig trade hubs considered as high betweenness nodes were identified based on their values.

6.2.2.2.4.4 Ego network analysis

A personal-network research design using ego-alter ties data type, along with ego network analysis, were used as described in a study by Simbizi et al., (2022). The type of ego neighbourhood was undirected. Ego network measures assessed, included size, number of directed ties, brokerage and betweenness of each ego. Egos with the largest networks, normalized brokerage and betweenness were identified as being powerful and central. **Table 16** gives a brief description of these measures as described by Borgatti et al., (2018).

Table 16: Descriptions of ego network measures used in the study according to Borgatti et al. (2018).

Network parameter	Definition
Size	Size of ego network
Ties	Number of directed ties.
Pairs	Number of ordered pairs.
Density	Ties divided by pairs
Broker	Number of pairs not directly connected.
Normalized broker	Broker divided by number of pairs.
Betweenness	It is when the ego between two other actors lies on the shortest directed path from one to the other.
Normalized betweenness	Compares the actual betweenness of the ego to the maximum possible

	betweenness in the neighbourhood of the size and connectivity of egos.
Ego betweenness	Betweenness of ego in own network
The network centralization index	It is calculated as the sum of differences between the centrality of the most central node and the centrality of every other node, divided by the maximum possible (which occurs when the network looks like a star).

6.2.2.2.4.5 Identification of pig trade hubs

Nodes (municipalities) that were most centrally located in the whole network analysis and identified as influential egos according to the size, normalized brokerage and normalized betweenness in the ego network analysis were identified as important pig trade hubs that could be targeted for disease surveillance.

6.3 Results

6.3.1 General information

Among 214 farmers interviewed, females were slightly more represented (52 %) than males (48 %).

6.3.2 Description of smallholder pig farmers (producers)

Smallholder pig farmers in the ECP acquired piglets from two main channels: commercial farms (European breeds) or other smallholder pig producers (European, indigenous, or mixed breeds). These pigs were managed under intensive, semi-intensive and free-range husbandry systems. Three categories of feed were used: commercial feed, supplements (crushed maize) and kitchen waste (swill). Commercial feed was produced by specialized companies in the country and was delivered to the farmers through different private distributors or agents. Extension services occasionally supported some pig cooperatives or individual smallholder farmers by contracting a service provider to supply this feed. The range of pigs kept by farmers per category was 1 - 65 for piglets; 1 - 37 for gilts; 1 - 81 for sows and 1 - 46 for boars. Appendix 18 gives the frequency of sales of live pigs and pig products as well as the total quantity of pigs sold (live pigs or carcasses) over the past 12 months by smallholder pig farmers in the ECP. Farmers were listed according to their municipalities. A total of 214 smallholder pig farmers were interviewed. Among these, 103 farmers (48%) do not frequently sell their pigs or pig products (at least one pig per year). Thirty-four farmers (16%) were involved in selling of their pigs and pig products on a regular basis (every six months or less) whereas 36% of farmers were not selling at all (Appendix 18).

6.3.3 Actors in the value chain and identification of biosecurity hotspots.

The following actors in the chain were identified: producers (farmers), meat traders, butcheries, supermarkets, processors and consumers (**Figure 14**). Different sub-categories among producers were identified, namely cooperatives or pig projects, backyard pig producers and pig clubs or "umbuto." The characteristics of these sub-categories are given in **Table 17** and they form part of socio-economic elements that were used in the value chain analysis. Other external actors included the Department of Rural Development and Agrarian Reform, different private companies selling commercial feed, medication and other inputs. By calculating the net profit margin, the following categories of actors in the value chain were found to add value to the selling activity of live pigs and pig products: backyard pig producers involved in pig clubs or "umbuto," meat traders, supermarkets, butcheries and processors (tshisanyama or grills).

The net profit margin per pig sold calculated for each of the four farmers involved in pig club or "umbuto" was found to be 80.8%; 74.2%; 83.2% and 73.7% (Appendix 19). The net profit margin per pig sold calculated for each of the three meat traders interviewed was 42.5%, 62.5% and 58.3% (Appendix 20). The calculated net profit margin per kg of pig meat according to twenty-three supermarket and butchery owners was 68.12% (Appendix 21). Finally, the net profit margin per kg of pig meat sold according to sixteen processors was found to be between 67.1% and 75.81% (Appendix 22).

The majority of farmers confirmed they sold more live pigs and their products in winter (from May to August) and during the festive season (from November to January) than any other season. Backyard pig producers were identified as biosecurity hotspots that could be targeted for disease surveillance.

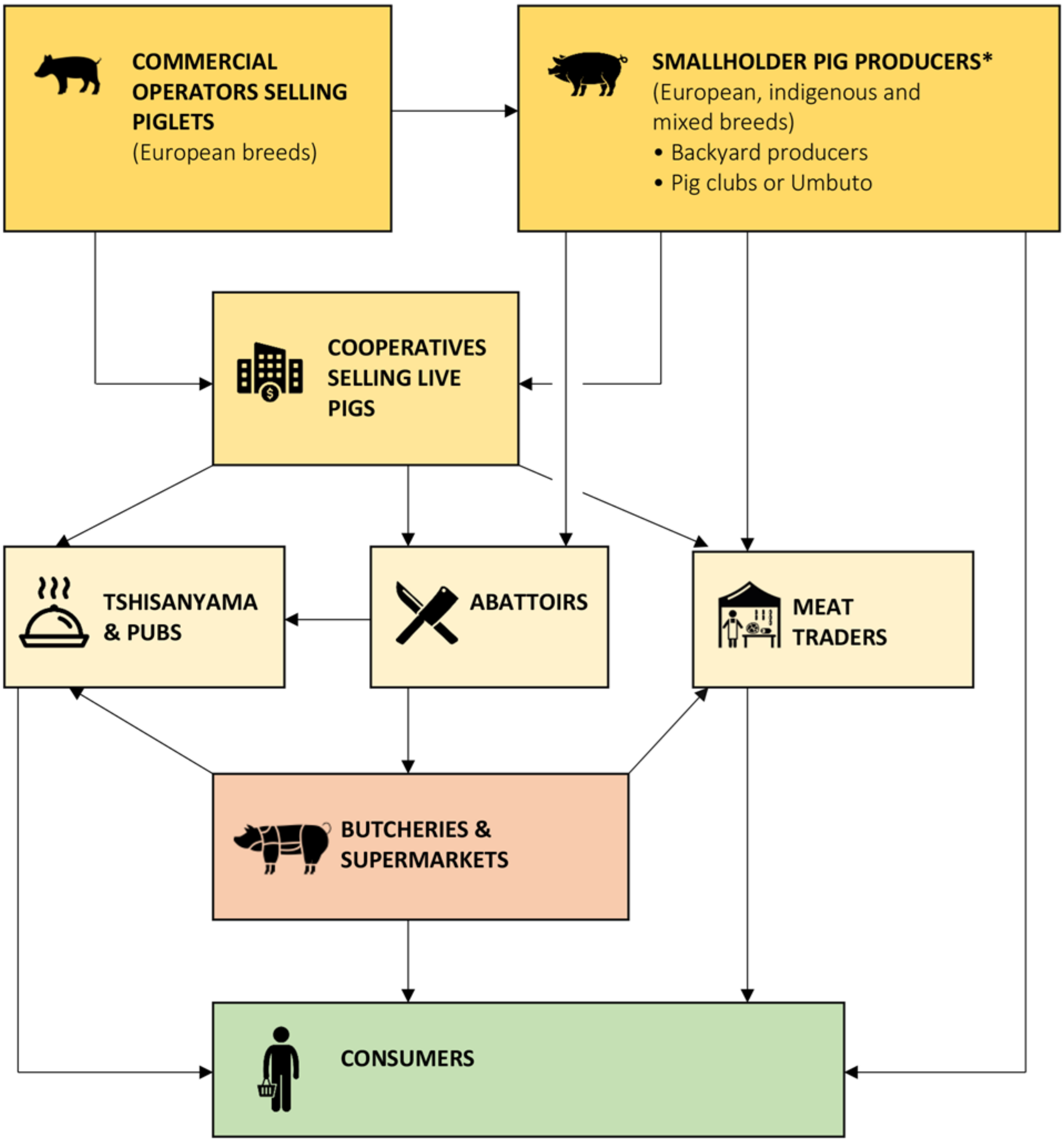

Figure 14: Pig value chain according to the survey done from February 2019 to July 2021 in the Eastern Cape Province.

Table 17: Characteristics of different actors involved in the smallholder pig value chain in the Eastern Cape Province according to the survey done from February 2019 to July 2021

Producers:	Characteristics
Cooperatives or pig projects	Selling for business purposes Equipped with basic knowledge on pig production; low biosecurity measures Herd size: ≥30 pigs Regular supply to a formal market after meat inspection at an abattoir Commercial feed used
Backyard pig producers	Selling for consumption and cultural purposes without meat inspection or a health permit. A very small percentage equipped with basic knowledge on pig production; no biosecurity measures Herd size: ≤30 pigs Occasional access to a formal market (mainly using informal market) Commercial feed plus kitchen waste
Pig clubs or "Umbuto"	Selling for business purposes and among the club members (cultural activity) without meat inspection or health permit Commercial feed plus kitchen waste
Meat traders:	Buying live pigs, slaughter and sell meat Selling meat per kg or per piece
Butcheries and supermarkets	Buying meat inspected by an abattoir Buying meat directly from local producers
Processors:	
Pubs or Tshisanyama and Grills	Selling meat obtained from butcheries and supermarkets
Street vendors	Selling meat obtained from butcheries and supermarkets

6.3.4 Involvement of participants in the movement of live pigs and pig products.

A total of 79% (169 from 214 farmers interviewed) reported details of destinations and origins of live pigs and pig products in the previous year, while 86% of other stakeholders interviewed (57 out of 66 stakeholders) reported these movements during the interviews.

6.3.4.1 Network visualization

The network of live pigs and pig products identified 34 nodes (**Figure 15**). Thirty nodes represented Eastern Cape municipalities whereas 4 nodes fell outside the province. These included municipalities from the Free State, KwaZulu-Natal, and Mpumalanga Provinces.

6.3.4.2 Betweenness centrality

Betweenness centrality results demonstrated that Nelson Mandela Bay (NMB) lay along every shortest path between every pair of other nodes; therefore, it was more central and powerful with a normalized betweenness value of 14, followed by Enoch Mgijima with a normalized betweenness value of 13 and King Sabata Dalindyebo (KSD) (normalized betweenness value of 12). The overall network centralization index was 12%.

6.3.4.3 Ego network analysis

Table 18 shows the ego network analysis results. The measures considered were normalized brokerage and ego betweenness. A larger ego network had the highest value of each of these measures. Higher normalized ego betweenness indicates how central the egos are in their network while a higher normalized brokerage implies that a high number of altars depends on the ego for a connection.

6.3.4.4 Identification of pig trade hubs

Based on centrality within the network, size, high brokerage and betweenness within their ego networks (**Table 18**), NMB, KSD and Enoch Mgijima were identified as important pig trade hubs of Eastern Cape Province. These hubs could be targeted for disease surveillance.

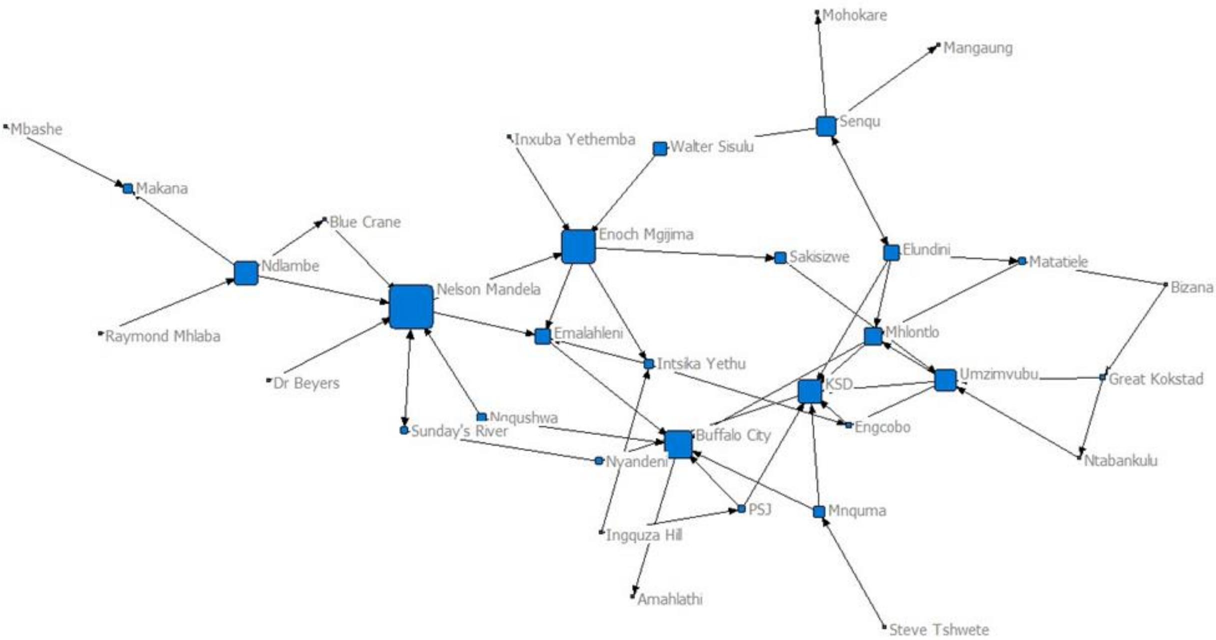

Figure 15: Network visualization for live pig movement and pig products in the Eastern Cape Province according to the data provided by participants during the survey conducted from February 2019 to July 2021 (Source: Ucinet®).

Table 18: Ego network measures of annual pig movements and products within ten Eastern Cape municipalities according to data provided by farmers and other actors in the value chain during the survey conducted from February 2019 to July 2021.

Ego (Municipality)	Size	Ties (directed)	Pairs	Density	N. brokerage	N. betweenness
NMB	7	2	42	4.76	0.95	33.33
KSD	7	3	42	7.14	0.93	14.29
E. Mgijima	6	2	30	6.67	0.93	26.67
Umzimvubu	6	3	30	10	0.90	30
Buffalo City	6	0	30	0	1	16.67
Mhlontlo	5	3	20	15	0.85	20
Elundini	4	2	12	16.67	0.83	25
Emalahleni	4	2	12	16.67	0.83	25
Ndlambe	4	1	12	8.33	0.92	25
Intsika Yethu	4	1	12	8.33	0.92	25

6.3.5 Reporting structure

The new reporting system to identify where more efficient use of existing resources could be utilized for the purpose of disease surveillance was structured based on the existing reporting system and the social network analysis results that identified pig trade hubs in the province (**Figure 16**).

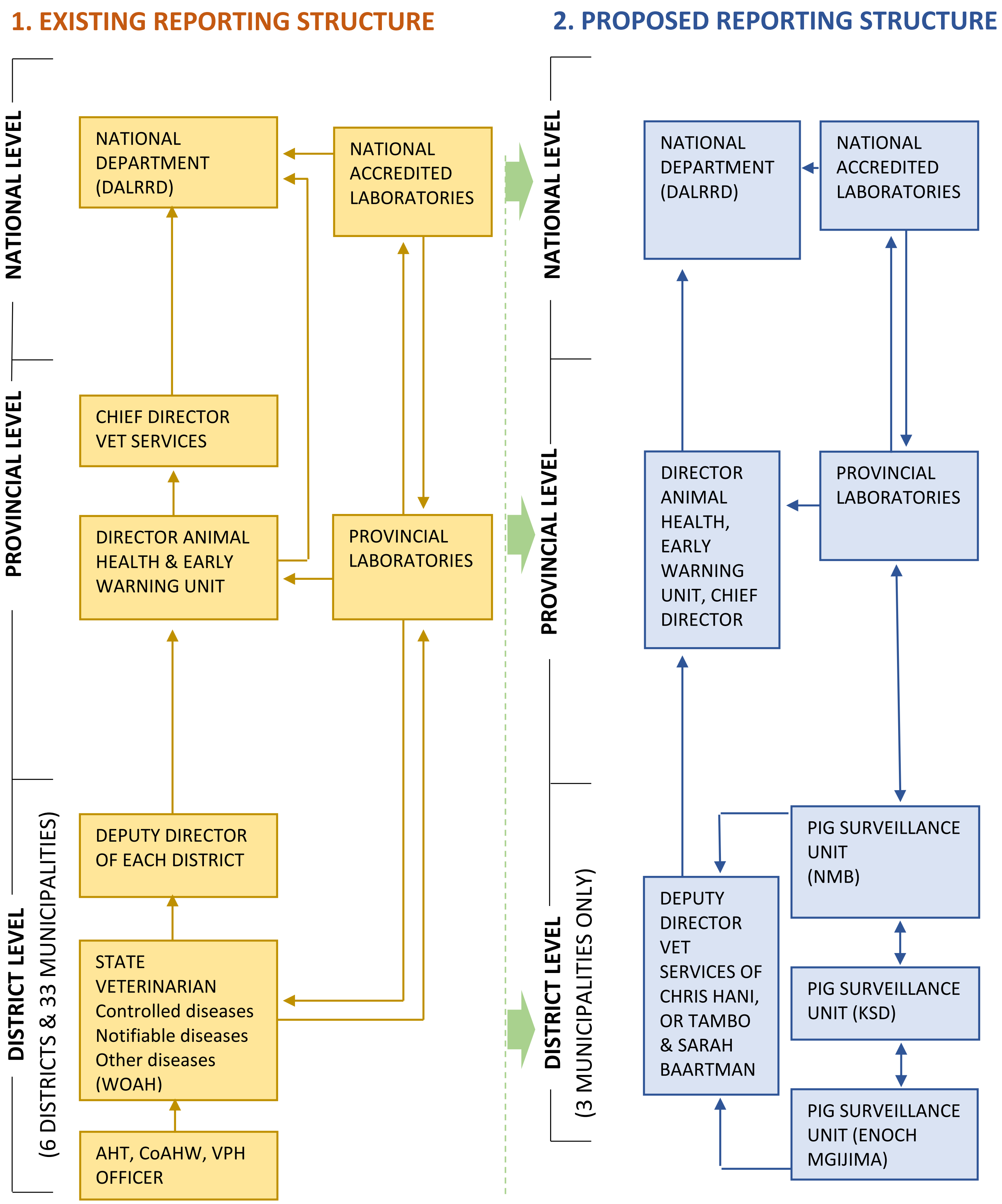

Figure 16: The existing reporting structure and a proposed reporting structure targeting surveillance at hotspots in the ECP.

6.4. Discussion

The smallholder pig value chain in the ECP is complex and involved two types of market: a formal market where live pigs were sent to abattoirs for meat inspection; thereafter the meat was retailed through formal channels like supermarkets before reaching the consumers. A second type was an informal market where pigs were sold live or slaughtered without necessarily passing through an abattoir for meat inspection. These findings confirmed the dual nature of the South African agricultural industry previously reported (Louw et al., 2017). Farmers used the informal market for two main reasons: firstly, the profit generated from the formal market was lower compared to the profit generated in the informal market. Our findings from abattoir owners revealed an average price of R27 per kg during the normal season and an average price of R32 per kg during the festive season. This was a selling price determined by abattoir owners and proposed to pig farmers prior to bringing their pigs to abattoirs. Upon receiving these pigs, abattoirs were responsible for slaughtering and selling the meat to butcheries, supermarkets, and pubs (**Figure 14**), with a varied markup. Secondly, the informal market was associated with some cultural activities including a practice called 'umbuto'. This practice involved a few smallholder pig farmers that set up a club with a joining fee. Each member had his turn to rear a pig. Once a pig had reached an average of 80 kg of bodyweight, it would be slaughtered, and the meat would be sold to other members of the club. The selling price could reach R130 per kg making this cultural related activity more profitable compared to the price determined by the abattoir. The purpose of this high selling price was to help the club members to financially support each other. Backyard pig producers who don't form part of umbuto were also selling their live pigs directly to meat traders, who were in turn selling the meat to consumers (**Figure 14**). This practice however presents a high risk for disease transmission, including zoonosis (Adhikari et al., 2021; N'da et al., 2022), because the informal slaughter of pigs by backyard pig producers and meat traders lacks proper meat inspection. It also makes it difficult to detect signs of economically important pig diseases like African swine fever, which means backyard pig producers could contribute to the transmission and maintenance of the disease in local pig populations (Penrith et al., 2013; van Rensburg et al., 2020). This can also explain a highest prevalence of cysticercosis reported in Xhosa-speaking people of ECP (Mafojane et al., 2003). Additionally, a recent study on backyard pig producers revealed low biosecurity measures for most of them in the province. It also revealed that farmers were selling and move their pigs or pig products without a permit or a health permit (Simbizi et al., under review). These backyard pig producers were therefore likely to take more risk and were less likely to comply with regulations (FAO, 2011) than other actors in the value chain. This segment of backyard pig producers was therefore considered as a biosecurity hotspot along the value chain, which could be targeted for disease surveillance.

The majority of live pigs and pig products were sold in winter (June-August) and the festive season (November-January), and these periods could be targeted for surveillance. Assessing seasonality of trade enables efficient timing of disease surveillance; that is, surveillance can be conducted during or just before the anticipated increase in trade (Mubamba et al., 2018). In Zambia, a period with an increased chicken trade occurred in the months associated with several commercial and social occasions (Mubamba et al., 2018).

The present study described different actors in the pig value chain in the ECP (**Figure 14**). The majority of farmers involved in pig farming and trading spent an average of R3000 to produce a 80-kilogram pig within 6 months. This amount includes the cost of commercial feed, medication, and electricity. To reduce the cost, some farmers involved in trade preferred to buy live piglets of ± 1 month at the cost of R500 and then spend on average R1500 to get the pigs to 80 kg after 6 months. By doing so, they save the money that they would spend on feed for lactating sows as well as on the electricity to keep the piglets warm during the first critical days. Similarly, farmers who were only selling piglets at a cost of R500 could make a quick profit as they did not have the added expense of medication and feed following the sale of the piglets except for the remaining sows. Although the calculated net profit margin for some actors in the chain (Appendix 19-22) did not include some parameters like fixed costs and labour, it revealed that trade of rural pigs could possibly be an income generating activity in the ECP as shown in other studies (Madzimure et al., 2014).

The findings from the Freeman betweenness centrality method revealed that three main municipalities, namely Nelson Mandela Bay; Enoch Mgijima and KSD, had the potential for controlling flows through the network, and for playing a gatekeeping or toll-taking role if disease surveillance was placed at these municipalities for early detection of any disease. Hence these municipalities could be considered as pig trade hubs. Ego network analysis results were also consistent with the centrality measures using the Freeman betweenness method, where Nelson Mandela Bay, KSD and Enoch Mgijima had a large ego size and high normalized brokerage (**Table 18**), making them centrally located within their ego networks as targets for disease surveillance. The assumption made for measuring the brokerage within an ego network is that unconnected alters are more likely to offer ego networks more benefits and influence its effective size (Burt, 1995). These SNA results, where bigger and more densely populated districts were identified as trade hubs, are similar to studies conducted in Kenya (McCarron et al., 2015), Zambia (Mubamba et al., 2018) and South Africa (Simbizi et al., 2022).

The existing reporting structure for veterinary services in the ECP is mainly based on passive surveillance and encompasses all the municipalities (**Figure 16**). The present findings show that pig surveillance should be focused on each identified trade hub, namely Nelson Mandela Bay, Enoch Mgijima and KSD municipalities. The existing human resources (state veterinarian, animal health technician or AHT, community animal health worker or CoAHW and veterinary public health officer or VPH) could therefore be located at these hubs, where they could regularly conduct active disease surveillance of backyard pig producers during the periods with increased trade, in the knowledge that they have a high likelihood of detecting and preventing spread of disease by doing so. This contrasts with the existing reporting system where state veterinarians wait for reports of an outbreak to reach them before action is taken. Active surveillance at the hubs would result in more rapid detection of disease outbreaks and a quick response using the same available capacity. In addition, prior knowledge of these hubs and actors could assist in disease control by isolating these components promptly (Poolkhet et al., 2013) through pig movement bans in the event of disease outbreaks. Furthermore, a continuous assessment of the disease situation in these hubs would serve to monitor the disease status for the region and allows trace back to the origin in the event of disease outbreaks. Finally, it also allows predictions of where subsequent outbreaks could move to and occur (Brioudes and Gummow, 2017). The surveillance units in the hubs would use the existing provincial laboratories for sample analysis and report to their respective Deputy Director from where reports would move up the system to the Director of Animal Health and the Chief Director at the provincial level and the Director of Animal Health at the national department (Department of Agriculture, Land Reform and Rural Development or DALRRD)

(**Figure 16**). Such a surveillance and reporting system would therefore be more sensitive to early detection of disease, be more cost-effective and risk-based.

Unlike for rural chickens where the movement of chickens was dominated by spent hens from commercial operations (Simbizi et al., 2022), the movement of live pigs and pig products in the present study was dominated by pigs from rural settings and these pigs could move between different municipalities with trade, hence posing a risk to the spread and propagation of infectious diseases. This was different to the findings from Pacific islands where farmers were trading within their communities which could reduce the risk of disease spread (Brioudes and Gummow, 2017). Another difference between the present findings and the results from a recent chicken value chain study in the ECP was that pigs from rural settings had access to abattoirs. In the chicken study, smallholder farmers could not use private abattoirs for slaughter and meat inspection because they didn't meet the requirements. This was described as a policy barrier to market entry for these farmers (Simbizi et al., 2022). The fact that smallholder farmers have access to abattoirs and with a high demand for pig meat across the province, probably stimulates abattoir owners to allow these pigs to be slaughtered at these facilities to meet this demand. This agrees with other studies confirming the growth of the smallholder pig farm subsector in the southern African region (Penrith, 2013; Penrith et al., 2019). Production processes for pig meat from smallholder pig farms in the province can therefore be improved to target retailthrough formal channels like supermarkets thuscreating more market opportunities for these farmers and contributing to food security. Consequently, these farmers need to be motivated to implement cost-effective biosecurity measures in order to mitigate any risk of infectious diseases along the value chain and help produce high quality meat. The expanding market opportunity for smallholder pig farmers has the knock-on benefit of providing more job opportunities and contributing to food security.

6.5 Conclusion

This is the first study done in the ECP, exploring a possibility of combining a pig value chain and social network analysis to improve surveillance in the ECP of South Africa. Three municipalities were identified as trade hubs based on the Freeman centrality method and ego-network analysis. Backyard pig producers in these municipalities were considered as biosecurity hotspot based on their trading practices and low biosecurity measures. The present findings provide a means for targeted surveillance in the rural pig sector of ECP. Based on these findings, a new reporting system within veterinary services which is risk-based and promotes early detection, containment and control of pig diseases could be introduced. Targeted surveillance focuses mostly on hotpot areas where a high risk of disease transmission exists thus allowing better and more efficient use of existing resources. The study also provides useful information on the value chain that could be used by policy makers within the government, to expand and invest in this sector for job creation, poverty alleviation and food security.

Author contributions

Vincent Simbizi designed the study, collected and analyzed data, and wrote the draft of the manuscript. Rebone Moerane had inputs on the introduction, methodology and discussion sections. Chrisborn Mubamba conducted detailed editing and had inputs on introduction, methodology and discussion. Bruce Gummow supervised the study design, data collection and analysis, conducted detailed editing and had inputs on the introduction, methodology, discussion and conclusion sections.

Data availability

The data for the study is available upon reasonable request from the corresponding author.

Declarations:

Ethical consideration

Permission to undertake this study was obtained from the Department of Agriculture, Land Reform and Rural Development (DALRRD) under section 20, the Directorate of Veterinary Services of the Department of Rural Development and Agrarian Reform (DRDAR), Eastern Cape Province and from the ethics committees of University of Pretoria (Faculty of humanities application ID: GW20180835HS; Faculty of Veterinary Science research committee application ID: REC109-18 and animal ethics committee application ID: V038-18).

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Consent to participate.

Every participant signed a consent form before the interview.

Conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

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CHAPTER 7

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

7.1 General discussion

The working hypothesis for this research was that updating the knowledge of pig and poultry diseases and studying the movement of pigs and poultry and value chains in relation to the propagation of the diseases in the rural ECP, would facilitate the establishment of a risk-based cost-effective surveillance system and an improved reporting system using the existing veterinary resources. Its overall objective was to propose a system for early detection of pig and poultry diseases, based on social network and value chain analyses, which could be combined using ensemble modelling. Ensemble modelling is the process of running two or more related but different analytical models and then synthesizing the results into a single outcome (Brioudes and Gummow, 2017a).

The work done in this thesis was broken down into a hazard analysis component, risk analysis component and a proposal on a placement of surveillance units in the trade hubs identified by social network analysis. A risk communication was also part of this model and was developed based on the research findings from Chapter 2 and 3. Each component had its own separate outcome. These components were combined to create an ensemble model for cost effective surveillance of the smallholder farming sector in the ECP.

Within this context, the hazard analysis comprised a literature review of pig and poultry diseases in the ECP from 2000-2020, using a computerized literature search from Web of Science and other relevant databases including the national database, the WOAH database and other relevant animal health reports from the province (Chapter 2). This was done with a view of determining the knowledge gap in pig and poultry diseases in the province and to identify what diseases (hazards) were of importance to smallholders in the ECP. A similar approach to identify hazards has been used in Pacific Islands in a model to identify the highest risk areas, risky practices and behaviors of animal disease introduction and/or spread (Brioudes and Gummow, 2016). This approach has also been recommended by the Food and Agriculture Organization (FAO) in quantitative risk analyses (FAO, 2011). Classical swine fever and Newcastle disease were the most reported diseases in pigs and chickens respectively, and they were consistently retrieved from both the national database and the WOAH database. They were therefore considered as target diseases around which the study could be focused. Apart from being diseases of economic importance, these two diseases were also constantly selected in a previous study during the prioritization exercise, whose criteria was considering five aspects of a pathogen, namely epidemiology, prevention/control, effects on economy/trade, zoonotic characteristics, and effect on society (Humblet et al., 2012).

The risk assessment included a questionnaire survey targeting chicken farmers, which involved a chicken value chain analysis and an assessment of trading practices to identify biosecurity hotspots as well as an identification of barriers to market entry for rural chicken farmers. This survey took place from February 2019 to June 2019. Secondly, a study on the movement of live chickens and chicken products in the province using social network analysis was carried out to identify trade hubs that could be targeted for disease surveillance based on their centrality within the network and their size and influence within their ego networks. This was done by conducting another survey targeting other actors identified by farmers in the first survey, from November 2020 to July 2021. The conclusions drawn from this risk assessment were: i) traders and their transport vehicles are biosecurity hotspots that could be targeted for disease surveillance within the chain, ii) three municipalities viz. Umzimvubu, King Sabata Dalindyebo (KSD) and Enoch Mgijima act as trade hubs where the interaction between chickens from rural settings and spent hens from commercial operations occurs and where resources can be focused, iii) the movement of spent hens from commercial operations that are transported over long distances and distributed in the rural areas and townships were a major risk for spread of chicken diseases, iv) the main barriers to market entry for chicken farmers included production constraints and current policy.

The second part of the risk assessment included an interview-based questionnaire survey targeting smallholder pig farmers and other participants involved in the smallholder pig value chain in the ECP which was conducted in two stages; from February to June 2019, as an initial survey targeting pig farmers, followed by a second survey from November 2020 to July 2021, based on information provided by pig farmers in the first survey. The second survey targeted abattoirs, meat traders, butcheries, supermarkets and pig processors identified by the farmers. The objective of this survey was to analyse the smallholder pig value chain and movement of pigs and pig products using SNA for informing targeted surveillance in the rural ECP, to better utilise the resources available and provide a cost-effective active surveillance system that promotes early detection of diseases, reduced mortalities, and increased production. The results showed that the sector was dominated by live pigs and pig products from rural settings that could be traded between municipalities, without meat inspection, posing a risk to the spread and propagation of diseases. The conclusions drawn from this part of the risk assessment were: i) backyard pig producers act as biosecurity hotspots due to the low biosecurity measures on their farms as well as their trade practices; ii) three municipalities in the ECP namely Nelson Mandela Bay, King Sabata Dalindyebo and Enoch Mgijima act as trade hubs; iii) active surveillance of backyard pig producers in these hubs could result in more rapid detection of disease outbreaks and a quicker response using the same available capacity; iv) a risk-based surveillance system within veterinary services based on targeted surveillance will improve the reporting system and provide more efficient use of available resources.

The approach used for the risk assessment is consistent with the thinking of others, that an in-depth understanding of demographics, social network structure and potential disease transmission pathways can help improve surveillance design and outbreak preparedness (Hernández-Jover et al., 2021). By identifying populations, areas and time in which early detection of a disease outbreak is most likely to be achieved, resources for animal disease surveillance can be appropriately deployed to yield maximum benefits (Hernández-Jover et al., 2021). This is particularly important in countries with limited resources, as is the case of the Eastern Cape Province of South Africa. The results from the risk assessment support the utilisation of social network analysis in risk-based surveillance approaches. As part of disease outbreak response preparedness, social network analysis can reveal influential nodes to be targeted in limiting disease spread quickly and efficiently (Poolkhet et al., 2013; Rasamoelina-Andriamanivo et al., 2014). This is essential for rapidly spreading diseases that impact international trade such as foot and mouth disease and African swine fever (Hernández-Jover et al., 2021). The present findings are supported by similar studies where the combination of social network analysis and value chain analysis has proven to be an excellent tool to identify trade hubs and biosecurity hotspots to be targeted for disease surveillance in the regions with limited resources (Brioudes and Gummow, 2017b; Mubamba et al., 2018a; Acosta et al., 2022; Simbizi et al., 2022). A value chain approach to animal diseases risk management, is also used by the FAO, where a detailed knowledge about animal population and behaviour of the people involved in all stages of livestock production and market was developed and enhanced through value chain analysis (FAO, 2011). The findings of such an analysis also provide a deeper understanding of the cultural and practical constraints that influence trade in developing countries.

Based on the results from the hazard analysis and risk assessment, the present project proposes a placement of surveillance units in each trade hub identified by social network analysis. Hence, the chicken surveillance units would be best placed in trade hubs of Umzimvubu, KSD and Enoch Mgijima whereas the pig surveillance units would be best placed in Nelson Mandela Bay, KSD and Enoch Mgijima municipalities.

The following table summarizes the three components of the model and the studies conducted.

Table 19: Studies conducted to improve pig and poultry disease surveillance in Eastern Cape Province of South Africa from 2019 to 2021 and how they relate to the components of the ensemble model.

Step of the ensemble model	**Component of the step**	**Study conducted**
I. Hazard analysis	Computer search and records on what has been published on pig and poultry diseases in the rural ECP.	A review of pig and poultry diseases in the ECP of South Africa, 2000-2020 (Chapter 2).
II. Risk assessment	Value chain and movement of pigs and poultry and their products	1. Using value chain and trade networks in the ECP of South Africa, as a basis for targeted rural chicken surveillance (Chapter 5). 2. Rationalizing resources through targeted active surveillance of smallholder pig farmers in the ECP of South Africa (Chapter 6).

III. Proposal on a placement of surveillance units in the trade hubs	a. Assessment of existing reporting system within veterinary services b. Assessment of trade hubs identified through social network analysis	1. Rationalizing resources through targeted active surveillance of smallholder pig farmers in the ECP of South Africa (Chapter 6).
Risk communication strategy	Demographics, farming practices and disease management	1. A study of rural chicken farmers, diseases and remedies in the ECP of South Africa (Chapter 3). 2. The role of smallholder pig farmers in the biosecurity of pig diseases in the ECP of South Africa using ASF as a model (Chapter 4).

The combination of these components can then be fitted into the following ensemble model for improving disease surveillance and reporting system in the pig and poultry sector of rural Eastern Cape Province of South Africa.

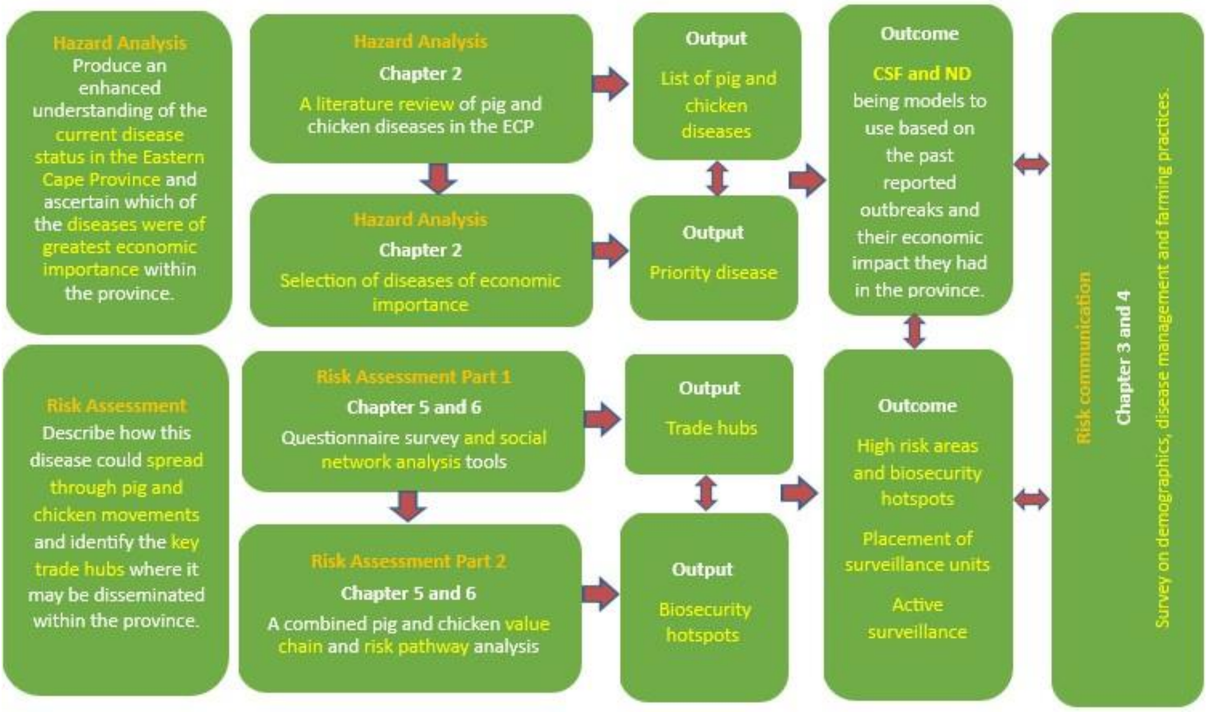

Figure 17: Ensemble model for identifying the components of a cost-effective targeted risk-based disease surveillance and reporting system in the pig and poultry sector of rural Eastern Cape Province of South Africa.

Due to financial constraints, animal disease detection in the ECP is mainly dependent on passive surveillance (DALRRD, 2021). This constitutes a major challenge with some diseases being underreported. Poor disease reporting (a low incidence of the reporting of unusual deaths and the flow of livestock-disease information between farmers and veterinary services) and lack of resources have been mentioned as a weakness to the control of infectious and transboundary diseases in South Africa (Mokoele et al., 2015). The lack of an active animal disease surveillance system that allows early detection of diseases and response strategies hampers effective disease control in the ECP where there is a critical shortage of veterinary resources. Except in the commercial sector where active surveillance is regularly performed by private veterinarians for export purposes, the communal sector is passively surveyed by provincial veterinary services. The Directorate of Veterinary Services in the ECP operates in 33 municipalities and, in each municipality, the reporting structure consists of para-veterinarians (a community animal health worker and an animal health technician) who report to the State veterinarian in terms of disease surveillance. The State veterinarian is required by law to report any controlled disease and compiles a disease report that is submitted to the Deputy Director of Veterinary Services in each district. The Deputy Director in turn reports to the early warning unit and to the Director of Animal health in the province. The latter reports to the Chief Director of Veterinary Services and to the National Department (Department of Agriculture, Land Reform and Rural Development or DALRRD). Provincial laboratories are part of this reporting structure because from time to time they receive samples from the State or private veterinarians and have an obligation to send the results back to them especially when there is an outbreak of a controlled disease. Such a reporting structure, however, is complex and doesn't promote early detection and containment of disease and is not risk-based.

The surveillance system proposed in this study (**Figure 17**) would only focus on three municipalities identified as high-risk areas (Umzimvubu, KSD and Enoch Mgijima for chickens; Nelson Mandela Bay, KSD and Enoch Mgijima for pigs), using the same existing officials working in these municipalities. A surveillance unit for each species would be formed in each hub and would be responsible for routine active surveillance targeting the biosecurity hotspots identified by this study namely backyard pig producers, chicken traders and their transport vehicles. These units would use the existing provincial laboratories for sample analysis and report to their respective Deputy Director from where reports would move up the system to the Director of animal health, the Chief Director at the provincial level and the Director of animal health at the national department (DALRRD) (**Figure 16** and appendix 23). This proposed system shows that a change in the current passive surveillance system, which encompasses 33 municipalities in the rural sector of ECP, to the placement of surveillance units in each trade hub would be more sensitive to early detection of disease, be more cost-effective and risk based. Each unit would include a state veterinarian and para-veterinarians (at least one animal health technician, one community animal health worker and a veterinary public health officer per unit). The use of para-veterinarians has been proven to be effective in national disease surveillance systems in developing countries (MacPhillamy et al., 2020) and serve as an important link to veterinary services, providing basic livestock health advice and treatments (Bugeza et al., 2017). The present research therefore brings a new way of improving disease surveillance and reporting using the existing veterinary resources efficiently. The research model may be applied to enhance disease surveillance for other livestock in other countries with minimal resources. The use of an ensemble model in this project was a novel approach to improve disease surveillance in the ECP and showed its value when solving problems that require multidisciplinary or multisectoral approaches. This model has also been successfully implemented to improve targeted allocation of resources to disease surveillance and risk communication in the Pacific Island countries (Brioudes and Gummow, 2017a). Furthermore, the application of this ensemble model has been successfully implemented in Zambia for the control of Newcastle disease in rural poultry of Eastern Zambia (Mubamba, 2018).

Findings from Chapter 2 could be used for a more targeted risk communication strategy. The conclusions drawn from this chapter were: i) the sector was dominated by pensioners with a low level of education; ii) village chickens could be a potential source of emerging diseases including virulent Newcastle disease virus (NDV) because of the lack of vaccination and biosecurity by farmers; iii) the use of antibiotics by untrained chicken farmers was a major public health concern as it could serve as a source of antimicrobial resistance (AMR); iv) the overall seroprevalence of Newcastle disease (ND), avian influenza (AI), avian infectious bronchitis (IB) and *Mycoplasma gallisepticum* (MG) in the province was found to be 69.2 % (95 % CI 51.9− 86.5%); 1.8 % (95 % CI 0.2− 3.4%); 78.5 % (95 % CI 74.9− 82%) and 55.8 % (95 % CI 41.3−70.3%) respectively with clustering found at the District level; v) chickens were exposed to the ND vaccine strains caused by spent hens from commercial operations that were being sold to rural farmers by traders and released into rural settings; vi) AI ELISA-positive samples were tested using HIs against the H5, H6 and H7-subtypes, but only H6-specific antibodies were detected (H6N2). Since these viruses can mutate and reassort among chickens, and they have the ability to infect humans (zoonosis), they require regular monitoring by the government and poultry industry.

Similarly, the findings from Chapter 3 could also be used as a basis for more targeted risk communication. The conclusions drawn from this section of the study were: i) the industry was dominated by female pensioners; ii) a low level of education, lack of training and reliance on the use of remedies to treat and prevent pig diseases for the majority of farmers were a key finding that could explain the poor implementation of biosecurity measures; iii) a poor knowledge of antibiotic use by farmers was likely to contribute to anti-microbial resistance (AMR) in these pigs; iv) smallholder pig farming could be a high risk for disease incursion and spread due to poor biosecurity measures; v) smallholder farms were frequently involving free-ranging pigs, swill feeding and informal trading; practices known to contribute to the spread of ASF and other communicable pig diseases; vi) the seroprevalence of ASF was found to be 0.01% (95% CI -0.003-0.015) with clustering found at the district level.

The research findings from both Chapter 2 and 3 are in agreement with other studies that confirmed that biosecurity and animal health management practices of smallholder livestock producers are often perceived as posing an increased risk for disease introduction and spread (Hernández-Jover et al., 2019) and therefore these findings can be used by the surveillance units in the trade hubs to improve the risk communication between farmers, veterinary services and other stakeholders on a regular basis. The demographics revealed the dominance of females in these two sectors, and this agreed with other findings (Gueye, 2000; Halimani et al., 2012; Sithole et al., 2019). Females should therefore be considered as an interest group that will greatly contribute to the development and expansion of these two sectors and address gender inequality (females are usually excluded from the farming business) within the province. Females contribute to food security in the rural area due to their socio-economic role in providing the basic household needs (i.e., food, school fees etc.) (Alders and Pym, 2009). The widespread use of non-conventional remedies by these farmers and limited contact between them and veterinary services exposes a gap in awareness of common pig and poultry diseases among smallholder farmers that needs to be addressed to enhance the quality of disease control and reporting. Some reports on traditional remedies for pig and poultry diseases and conditions in Sub-Saharan Africa have been published (Waihenya et al., 2002a; Waihenya et al., 2002b; Mwale et al., 2005; Dahourou et al., 2021), but their widespread use needs further investigations on their safety and efficacy. Such investigations could contribute to ethno-veterinary medicine. The use of antibiotics by smallholder pig and poultry farmers was an important public health issue when analyzing the findings from both chapter 2 and 3. The fact that many of these farmers had a low level of education and did not receive any training on antibiotic usage poses a risk of antimicrobial resistance in these animals and rural communities who consume them, resulting in increasing antimicrobial therapy failure (Mallioris et al., 2022). Additionally, it was found that many of these farmers were relying on the use of these antibiotics instead of promoting good biosecurity measures on their farms. Another contributing factor was their easy access to these antibiotics as over-the-counter products through the local licensed selling companies. Tackling the issue of antimicrobial use in this sector will need involvement of all the stakeholders and this can be incorporated into the risk communication strategy.

The findings from Chapter 2 and 3 provide a better picture of what farmers need in terms of training. They can serve as a guideline to be used, in a participatory approach, by veterinary and agricultural extension services to enhance extension service delivery and to capacitate smallholder farmers in the areas identified as trade hubs. Such real-time exchange of information would improve disease reporting. Veterinary services in the ECP will have to consider all the possible factors that will lead to farmers' participation in disease reporting. For instance in Australia, factors that include animal kept (species, breed etc.), the level of experience of smallholders, the location as well as the existing local networks used by the smallholders were found to be the influencing characteristics that should be considered when developing strategies for improving their engagement with the surveillance system in the country (Hernández-Jover et al., 2019). Continuous communication about the risks should be carried out with key stakeholders. In case different stakeholders may have different perceptions of a particular risk and different opinions on the risk reduction strategy to adopt, a consultative approach involving the value chain stakeholders, along with the animal health and livestock production authorities, is essential to maintain continuous risk communication throughout the different steps of the risk management process, to ensure a more transparent decision-making approach and to reach an agreement on the contribution of different stakeholders to the adopted risk mitigation measures (Brioudes, 2016). These units would be responsible for training the smallholder farmers in biosecurity and antimicrobial use or in other areas identified by farmers themselves using the existing farmer's platforms. Under the coordination of these units, other stakeholders (i.e., SAPA, SAPO etc.) could use these existing platforms to engage with smallholders on many challenges faced by farmers with the aim of increasing production and ensure food security. Such platforms or clubs could be used by veterinary services to collect syndromic data which is a useful disease reporting tool and an effective means of alerting authorities to disease incursion as it was successfully done in Zambia (Mubamba et al., 2018b). The implementation of one Health approach as part of risk communication in the trade hubs would be beneficial. One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems (Zinsstag et al., 2023). This approach would mobilize multiple sectors, disciplines, and communities at varying levels of society to work together for antimicrobial surveillance in pigs and chickens and other livestock and to sensitize the community about important zoonotic diseases found in this study such as avian influenza subtype H6. Neglected zoonotic diseases such as leptospirosis could also be investigated via one Health while promoting good farming practices. This approach would help to improve the livelihoods of smallholder farmers and communities, considering that ECP is among the provinces with the highest rate of HIV/AIDS in the country (Abong'o and Momba, 2008).

7.2 Conclusions and recommendations

The results of this research led to an update and a better understanding of the significance and spread of pig and chicken diseases in the Eastern Cape Province of South Africa. It also gave clarity on the farmers' demographics and pig and chicken value chains in the rural settings of ECP and the way farmers dealt with infectious diseases. Along with the biosecurity and trade hotspots (hubs) identified in the study, this information provides some insights for better targeted animal disease surveillance in the province. The work conducted in this study provides a practical framework for ECP to use and replicate in the future for a more rational and transparent allocation of scarce resources towards animal disease prevention and control. The present study may present some limitations and gaps that should be addressed by future researchers. However, the results presented in this thesis provide the basis for a shift in disease control strategy and change in behaviour by veterinary services using the existing resources. The improved surveillance will lead to improved reporting system which will be risk based and sensitive to early detection of disease, therefore reducing mortalities and increase production. This approach is in line with the provincial development plan (PDP) included in the new DRDAR's strategic plan (2020-2025) that says "DRDAR will ensure accelerated agricultural development and food security for all, increase the total area of land under agricultural production and the number of people, households and enterprises that are active in the agriculture sector". It is also in line with the new Agricultural Economic Transformation Strategy whose aim is to ensure increased crop and animal production (DRDAR, 2020). Extending this work to other provinces and other livestock species would significantly improve livestock disease surveillance in South Africa and other sub-Saharan countries with similar rural livestock profiles. This will enhance food security and income generation among vulnerable members of the rural communities hence increasing the Gross Domestic Product (GDP) of the province.

The following table gives details of recommendations based on the conclusions from each research study and targets for implementation:

Table 20: Recommendations cross-referenced to the conclusions of the research and targets for implementation.

METHODS	CONCLUSIONS	RECOMMENDATIONS	TARGETS
Chapter 2 Literature review on pig and chicken disease in the province from 2000 to 2020	Classical swine fever and Newcastle disease were the most reported diseases in pigs and chickens. Very little information is available on pig and chicken diseases and zoonosis in the province.	More surveys need to be done to have accurate information on pig and chicken diseases and a proposed Animal Health Information System (AHIS) in the province	Provincial animal health authorities
Chapter 3 A study of rural chicken farmers, diseases and remedies in the Eastern Cape Province of South Africa	1. The industry is dominated by pensioners with a low level of education;	1. Involving and training youth in chicken farming will dynamize the sector and help to transform the agricultural sector to deliver on rural economic development and job creation as well as to reduce the migration of the youth to cities to seek opportunities.	Provincial animal health authorities, smallholder chicken farmers and veterinary services.
	2. Village chickens were found to be a potential source of emerging diseases including virulent Newcastle disease virus (NDV) because of the lack of vaccination and biosecurity by farmers;	2. Promoting vaccination of chickens in the rural areas of ECP through annual vaccination campaigns and improved biosecurity should be encouraged.	Smallholder chicken farmers and ECP veterinary services.
	3. The use of antibiotics by untrained chicken farmers was a major public health concern as it could serve as a source of antimicrobial resistance (AMR);	3. Training farmers on the use of antibiotics will lower the risk of antimicrobial resistance (AMR) in both humans and chickens.	Provincial animal health authorities, ECP veterinary services, ECP agricultural extension services and other stakeholders including SAPA and Veterinary pharmaceutical companies

	4. Chickens were exposed to H6N2 viruses. These viruses found to be able to mutate and reassort among chickens, had ability to infect humans (zoonosis) which requires their regular monitoring by the government and poultry industry.	4. A concept of one Health will be beneficial to deal with zoonosis in the rural communities.	Provincial animal and human health authorities and other stakeholder including the NICD
Chapter 4: The role of smallholder pig farmers in the biosecurity of pig diseases in the Eastern Cape Province of South Africa using ASF as a model	1. A low level of education, lack of training and reliance on the use of remedies to treat and prevent pig diseases for the majority of farmers contributed to the poor implementation of biosecurity measures.	1. Training on biosecurity and antibiotic usage will address this issue.	ECP veterinary services, ECP agricultural extension services and stakeholders including SAPO
	2. A poor knowledge of antibiotic use by farmers posed a risk for anti-microbial resistance (AMR) in pigs.	2. Same as above	ECP veterinary services, ECP agricultural extension services and stakeholders including SAPO and Veterinary pharmaceutical companies
	3. Smallholder pig farms are a risk for disease incursion and spread due to poor biosecurity measures.	3. Improved farming practices, apply basic biosecurity measures, access to market for incentives to report pig diseases	ECP veterinary services, ECP agricultural extension services and stakeholders including SAPO
	4. Smallholder farms can contribute to the spread of ASF and other communicable pig diseases because they frequently involve free-ranging pigs, swill feeding and informal trading.	4. Basic biosecurity measures that include confinement, limiting use of swill or proper treatment of the swill (sufficiently cooked) as well as market opportunities for farmers should be advocated	Smallholder pig farmers, ECP veterinary services, Provincial animal health authorities

Chapter 5: Using value chain and trade networks in the Eastern Cape Province of South Africa, as a basis for targeted rural chicken surveillance	1. Traders and their transport vehicles are biosecurity hotspots that could be targeted for disease surveillance within the chain,	The ECP has well defined trade hotspots for pig and poultry diseases – therefore disease surveillance in these trade hotspots will limit disease spread.	Surveillance units, ECP veterinary services including provincial laboratories, SAPO, ECP agricultural extension services
	2. Three municipalities viz. Umzimvubu, King Sabata Dalindyebo (KSD) and Enoch Mgijima act as trade hubs where interaction between chickens from rural settings and spent hens from commercial operations occurs and where resources can be focused	2. Same as above	Surveillance units, ECP veterinary services including provincial laboratories, SAPA, ECP agricultural extension services
	3. The movement of spent hens from commercial operations that are transported over long distances and distributed in the rural areas and townships were a major risk for spread of chicken diseases	3. The practical way is to use these defined trade hotspots to conduct active surveillance	Surveillance units, ECP veterinary services including provincial laboratories, SAPA, ECP agricultural extension services.
	4. The main barriers to market entry for chicken farmers included production constraints and current policy.	4. Removal of these barriers will allow to sustain and expand rural poultry farming by giving farmers access to the market, consequently this will provide jobs and contribute to poverty alleviation.	Provincial authorities
Chapter 6: Rationalizing resources through targeted active surveillance of	1. Backyard pig producers act as biosecurity hotspots due to the low biosecurity measures on their farms as well as their trade practices.	The placement of surveillance units in each trade hub using existing veterinary resources and responsible for routine active	Surveillance units, ECP veterinary services including provincial laboratories,

smallholder pig farmers in the Eastern Cape Province of South Africa	2. Three municipalities in the ECP namely Nelson Mandela Bay, King Sabata Dalindyebo and Enoch Mgijima act as trade hubs.	surveillance in backyard pigs would be more sensitive to early detection of disease, be more cost- effective and risk based. These units and other stakeholders will be responsible for training of farmers in biosecurity and good farming practices and other areas identified by farmers themselves using the existing farmers' association or clubs. Future research evaluating or modelling the economic benefit of the suggested targeted active surveillance activity compared to the *status quo*.	SAPO, ECP agricultural extension services
	3. Active surveillance of backyard pig producers in these hubs could result in more rapid detection of disease outbreaks and a quicker response using the same available capacity;		
	4. A risk-based surveillance system within veterinary services based on targeted surveillance will improve the reporting system and provide more efficient use of available resources.		

7.4 References

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APPENDICES

Appendix 1**:** List of databases from Web of Science used in the study:

WOS: Web of Science Core Collection
BCI: Biosis Citation Index
CABI: CAB Abstracts®& Global Health®
CCC: Current Contents Connect
DRCI: Data Citation Index
DIIDW: Derwent Innovations Index
FSTA: Food Science and Technology Abstract
KJD: Korean Journal Database
MEDLINE
RSCI: Russian Science Citation Index
SciELO: SciELO Citation Index
ZOOREC: Zoological Record

Appendix 2: List of zoonotic diseases found in this study.

Disease	Source
Avian influenza	Web of Science, DALRRD Database, WOAH database
Hepatitis E virus	Web of Science
Newcastle disease	Web of Science, DALRRD database, WOAH database, All Eastern Cape veterinary laboratory records
Enterococcus	Web of Science
Salmonella	Web of Science
Colibacillosis	Web of Science, All Eastern Cape veterinary laboratory records
Cysticercosis	Web of Science, DALRRD database
Chlamydiosis	WOAH database
Norovirus	Web of Science
Nocardiosis	Grahamstown laboratory records
Campylobacteriosis	Web of Science

Appendix 3: Pig and poultry diseases reported in the National Database (DALRRD) from 1999 to 2019 (DAFF, 2020)

Disease	Species	District	Date	Number of reported outbreaks
Mycoplasma gallisepticum	Avian	Harry Gwala*	1999	2
	Avian	Harry Gwala*	2000	4
	Avian	Alfred Nzo	2000	1
	Avian	O.R Tambo	2001	1
	Avian	Harry Gwala*	2001	2
Newcastle disease	Avian	Harry Gwala*	1999	4
	Avian	Harry Gwala*	2001	1
	Avian	Amathole	2002	2
	Avian	Buffalo City	2003	2
	Avian	Harry Gwala*	2004	1
	Avian	Alfred Nzo	2004	1
	Avian	Nelson Mandela Bay	2005	4
	Avian	Buffalo City	2005	5
	Avian	Chris Hani	2005	3
	Avian	Harry Gwala*	2005	3
	Avian	Sarah Baartman	2005	1
	Avian	Amathole	2005	1
	Avian	Amathole	2005	1
	Avian	Amathole	2005	1
	Avian	Sarah Baartman	2006	4
	Avian	Nelson Mandela Bay	2006	5
	Avian	Buffalo City	2006	2
	Avian	Sarah Baartman	2006	1
	Avian	Chris Hani	2006	1

Avian	Chris Hani	2006	1
Avian	Chris Hani	2007	1
Avian	Buffalo City	2008	1
Avian	Alfred Nzo	2008	4
Avian	Chris Hani	2008	2
Avian	O.R Tambo	2008	2
Avian	Amathole	2008	1
Avian	Alfred Nzo	2009	11
Avian	Nelson Mandela Bay	2009	1
Avian	Buffalo City	2009	2
Avian	Buffalo City	2010	5
Avian	Nelson Mandela Bay	2010	1
Avian	Sarah Baartman	2010	2
Avian	Buffalo City	2011	1
Avian	Amathole	2012	1
Avian	O.R Tambo	2013	2
Avian	Chris Hani	2013	1
Avian	Amathole	2014	2
Avian	Sarah Baartman	2014	1
Avian	Amathole	2014	2
Avian	Chris Hani	2015	1
Avian	Chris Hani	2015	1
Avian	Alfred Nzo	2015	2
Avian	Amathole	2015	1
Avian	O.R Tambo	2015	1
Avian	Amathole	2015	1
Avian	Amathole	2016	4
Avian	Joe Gqabi	2016	1
Avian	Sarah Baartman	2016	3

	Avian	O.R Tambo	2017	1
Gumboro	Avian	Sarah Baartman	2002	1
	Avian	Amathole	2009	1
Fowl cholera	Avian	Amathole	2010	1
	Avian	Joe Gqabi	2010	1
Avian infectious bronchitis	Avian	Nelson Mandela Bay	2005	1
	Avian	Amathole	2011	1
Fowl pox	Avian	Harry Gwala*	1999	2
	Avian	Harry Gwala*	2000	1
	Avian	Joe Gqabi	2000	1
	Avian	Harry Gwala*	2002	4
	Avian	Amathole	2002	3
	Avian	Joe Gqabi	2003	1
	Avian	Amathole	2003	1
	Avian	Alfred Nzo	2003	1
	Avian	Joe Gqabi	2009	2
	Avian	O.R Tambo	2010	1
	Avian	Amathole	2016	1
Coccidiosis	Avian	Harry Gwala*	1999	4
	Avian	Joe Gqabi	1999	1
	Avian	O.R Tambo	1999	1
	Avian	O.R Tambo	1999	1
	Avian	O.R Tambo	2000	3
	Avian	Alfred Nzo	2000	2
	Avian	Harry Gwala*	2000	1
	Avian	Harry Gwala*	2001	3
	Avian	Buffalo City	2001	1
	Avian	Harry Gwala*	2002	2

	Avian	Alfred Nzo	2002	1
	Avian	Amathole	2002	1
	Avian	Amathole	2003	2
	Avian	O.R Tambo	2004	1
	Avian	Harry Gwala*	2004	1
	Avian	Amathole	2006	2
	Avian	Amathole	2007	1
	Avian	Sarah Baartman	2007	1
	Avian	O.R Tambo	2007	1
	Avian	Amathole	2010	1
	Avian	Amathole	2011	3
	Avian	Amathole	2011	1
	Avian	Buffalo City	2011	1
	Avian	Amathole	2018	1
Salmonella enteritidis	Avian	Sarah Baartman	2017	1
Avian infectious laryngotracheitis	Avian	O.R Tambo	2008	1
Avian leukosis	Avian	Harry Gwala*	1999	4
	Avian	Harry Gwala*	2000	3
	Avian	Harry Gwala*	2001	1
	Avian	Alfred Nzo	2002	1
Classical swine fever	Swine	Chris Hani	2005	4
	Swine	Amathole	2005	2
	Swine	Joe Gqabi	2005	2
	Swine	Buffalo City	2005	30
	Swine	Sarah Baartman	2005	3
	Swine	Chris Hani	2005	10

	Swine	Nelson Mandela Bay	2005	6
	Swine	Chris Hani	2005	9
	Swine	Amathole	2005	2
	Swine	Amathole	2005	3
	Swine	Chris Hani	2006	5
	Swine	Buffalo City	2006	12
	Swine	Sarah Baartman	2006	1
	Swine	Nelson Mandela Bay	2006	6
	Swine	Amathole	2006	1
	Swine	Chris Hani	2006	3
Swine erysipelas	Swine	Chris Hani	2008	1
	Swine	Alfred Nzo	2013	1
Cysticercosis (*Cysticercus cellulosae*)	Swine	Buffalo City	2002	1
	Swine	Alfred Nzo	2003	2
	Swine	Harry Gwala*	2003	1
Coccidiosis	Swine	Amathole	2012	1

*Umzimkhulu found in the national database is a town in Harry Gwala District Municipality (KwaZulu-Natal). Until 1 March 2006, the town was part of an exclave of the Eastern Cape Province.

Appendix 4: Pig and poultry diseases retrieved from Grahamstown veterinary laboratory records.

Disease	Species	Year	Month
Aspergillosis	Avian	2012	Sep
Nocardiosis	Avian	2012	Nov
Roundworms	Avian	2012	Nov-Dec
E. coli	Swine	2012	Nov
Chicken pox	Avian	2013	Jan
Bacterial septicaemia	Avian	2013	Feb-Sep
Colisepticaemia	Avian	2013	Feb
Stunted Growth Syndrome	Avian	2013	Mar
Colibacillosis	Avian	2013	May-Nov
Staphylococcus epidermidis	Avian	2013	May
Bacterial pneumonia	Avian	2013	Jul
Klebsiellosis	Avian	2013	Sep
Newcastle disease	Avian	2013	Dec
Colibacillosis	Avian	2014	Jan-Dec
Colibacillosis	Swine	2014	Jan-Oct
Mycoplasma	Avian	2014	Mar
Roundworms	Avian	2014	Mar-Aug
Roundworms	Avian	2014	Apr-Sep
Hypothermia	Avian	2014	Apr
Pasteurellosis	Swine	2014	Apr
Roundworms	Swine	2014	Apr
Bacterial septicaemia	Avian	2014	Jul
Newcastle disease	Avian	2014	Aug-Nov

Perforating ulcer and Peritonitis	Swine	2014	Sep
E. coli	Avian	2014	Sep
Aspergillosis	Avian	2014	Jan
Gastric ulcer	Swine	2014	Nov
Newcastle disease	Avian	2015	Mar
Bacterial pneumonia	Avian	2015	May
E. coli	Avian	2015	May
Pneumonia	Swine	2015	Sep
Colibacillosis	Avian	2016	Jan
Coccidiosis	Avian	2016	Jan
Pneumonia	Swine	2016	Sep
Roundworms	Swine	2016	Sep
Ascites	Avian	2016	Oct
Colibacillosis	Swine	2016	Oct
E. coli	Swine	2016	Oct
Anaemia and Babesiosis	Swine	2016	Oct
Coccidiosis	Swine	2017	Jan
Asphyxiation	Swine	2017	Mar
Pneumonia and necrotic enteropathy	Swine	2017	May
Colibacillosis	Avian	2017	Jul
Coccidiosis	Avian	2017	Jun
E. coli	Avian	2017	Jul
Internal parasite infestation	Avian	2018	Jun

Appendix 5: Pig and poultry diseases retrieved from Queenstown veterinary laboratory records.

Disease	Species	Year	Month
E. coli	Avian	2018	March
E. coli	Porcine	2018	March
Pulmonary Hypertension syndrome	Avian	2018	March
Avirulent ND	Avian	2018	April
Coccidiosis	Avian	2018	April
Infectious coryza	Avian	2018	April

Appendix 6: Pig and poultry diseases retrieved from Middelburg Veterinary Laboratory Records

Disease	Species	Year	Month
Newcastle disease	Avian	2007	Aug
	Avian	2014	Sep
	Avian	2015	Jun-Aug
E. coli	Avian	2009	-
Enterobacteria	Avian	2009	-
Chicken pox	Avian	2017	June
Chron. Resp. disease	Avian	2017	June
Colibacillosis	Avian	2018	Aug
Peritonitis	Avian	2019	Apr
Parvovirus	Porcine	2007	Jul
Erysipelotrix	Porcine	2007	Aug
Klebsiella pneumonia	Porcine	2009	Oct-Nov
Colibacillosis	Porcine	2009	Sep
Skin condition	Porcine	2009	Sep
Pneumonia	Porcine	2010	Oct
Thymus Lymphoma	Porcine	2014	May
C. perfringens. type A	Porcine	2016	Dec
SMEDI[1]	Porcine	2018	Feb

[1] Stillbirth, Mummification, Embryonic death and Infertility

Appendix 7: Pig and poultry diseases reported in the WAHID interface from 2005 to 2020 (WOAH, 2020a).

Disease	Species	Year	Month
Fowl pox	Avian	2005	Jan-June
Avian infectious bronchitis	Avian	2005	Jan-June
	Avian	2007	Jul-Dec
	Avian	2010	Jan-July
	Avian	2011	Jan-Dec
	Avian	2013	Jan-Jun
	Avian	2014	Jul-Dec
	Avian	2016	Jan-Dec
Newcastle disease	Avian	2005-2009	Jan-Dec
	Avian	2010	Jan-Jun
	Avian	2018	Jan-Jun
LPAI (poultry)	Avian	2007	Jan-Jun
	Avian	2013	Jul-Dec
	Avian	2014	Jan-Jun
	Avian	2016	Jan-Jun
	Avian	2017	Jan-Jun
	Avian	2018	Jan-Dec
HPAI	Avian	2006	Jan-Dec
	Avian	2011	Jan-Dec
	Avian	2012	Jan-Dec
	Avian	2013	Jan-Jun
	Avian	2017-2018	Jan-Dec
Gumboro	Avian	2009	Jul-Dec
	Avian	2016	Jul-Dec
Mycoplasmosis	Avian	2005	Jul-Dec
Fowl cholera	Avian	2006	Jan-Jun

	Avian	2010	Jul-Dec
Classical swine fever	Swine	2005	Jul-Dec
	Swine	2006	Jan-Dec
	Swine	2007	Jul-Dec
African swine fever*	Swine	2020	Jan-Jun

* Disease reported to WOAH but not found in the national database

Appendix 8: Remedies used by village chicken farmers in the ECP.

Remedies	Active ingredient	Usage by farmers (%)
Traditional:		
Aloe ferox Mill.	Cape Aloe Ferox Gel. Vitamin C or Ascorbic acid (Water Soluble) Vitamin B5 or Pantothenic acid. Vitamin A palmitate. Vitamin E or Tocopherol (Oil Soluble) Vitamin B6 or Pyrodoxine (Oil soluble) Vitamin B2 or Riboflavin.	28.23
Zifozonke	Sodium permanganate	5.71
Mthuma*	Not found	0.41
Fish oil		0.55
Sugar		0.48
Salt		0.95
Epsom salt	Magnesium sulfate	0.59
Engine oil		1.31
Jeyes fluid	p-chloro-m-cresol, Tar acids, Propan-2-ol, Terpineol	0.48
Karbadust	Carbaryl (Carbamate)	0.48

Blue Death	Carbaryl	0.76
Ashes		0.48
Sniff		0.95
Garlic with vinegar		0.37
Madubula		0.78
Mbanga-mbanga	Not found	0.28
Vicks		0.68
Deadline	Flumethrin	0.22
Parafin		0.74
Sibabile		2.70
Total usage		**47.15**
Sulpha products:		
Cosumix Plus	Sulphachloropyridazine & Trimethroprim	6.23
ESB3	Sulphachloropyrazine sodium	1.9
Coliprim	Sodium Sulphachloropyridazine & Trimethroprim	1.43
Sulfazine 16%	Sulphadimidine Sodium	0.95
Triple Sulfa	Na-sulphamerazine, Na-sulphamethazine, Na-sulphathiazole sesquihydrate	0.95
Norotrim	Sulphonamide	0.55
Total usage		**12.01**

Tetracyclines		
Oxytetracycline	Oxytetracycline HCl	0.48
Terramycin powder	Oxytetracycline HCl	10.75
Hi-Tet	Oxytetracycline HCl	3.33
Doxysyrup	Doxycycline hyclate	0.95
Terramycin Liquid	Oxytetracycline HCl	1.43
Doxymycin	Oxytetracycline, sodium sulphacetamide, cetrimide	0.48
Total usage		**17.42**
Vaccines		
Newcastle (Lasota)		6.91
Gumboro		4.80
IB		0.90
Total usage		**12.61**
Supplements		
Stresspac	Vitamins and Minerals	10.33
SE Care powder	Vitamin E and Selenium	0.48
Total usage		**10.81**

* *Solanum aculeastrum*

Appendix 9: List of villages sampled and number of chickens per village, ECP, from August 2019 to February 2020

District	Village's name	Household	Local Municipality	Number of chickens sampled
Chris Hani	Bengu	3	Emalahleni	7
	Machubeni	1		2
	Mtsheko	7		14
	Hala 1	3		38
	Hala 2	3		42
	Kavara	7		90
	Tsazo	3	Ngcobo	8
	Beyele	3		12
	Khalinyanga	4		9
	Tshamazimba	2	Intsika Yethu	10
	Woodhouse	3		35
	Deckert's Hill	1		8
	Qamata	4		72
	Tsengiwe	1	Sakhisizwe	7
	Upper Indwana	1		6
	Stokwe's basin	1		8
	Machibini	4	Enoch	7
	Zola	3	Mgijima	9
	Tambo	2		8

	Cradock	2	Inxuba Yethemba	19
Alfred Ndzo	Ramatli	1	Matatiele	6
	Nchodu	2		9
	Zwelitsha	3		6
	Nomlacu	1	Mbizana	8
	Nikwe	2		8
	Nkantolo	2		6
	Yandlala	1	Ntabankulu	8
	Dambeni	2		9
	Mpisini	2		6
	Goso	1	Umzimvubu	7
	Saphukanduku	1		6
	Rode	3		9
Joe Gqabi	Mzamomhle	2	Walter Sisulu	5
	Maize field	2		7
	Aliwal North	2		8
	Mogesi	2	Senqu	9
	New Rest	2		6
	Zava	3		8
	Ezingonyameni	2	Elundini	9

	Luzi Port	1		7
	Luzi	2		7
Metropolitan	Qalashe	3	Buffalo City	17
	Restini	2		17
OR Tambo	Kambi	2	KSD	12
	Nkalane	1		5
	Mqanduli	2		5
	Bala	1	Ingquza Hill	12
	Malangeni	2		6
	Mhlanga	1		1
	Moyeni	3	Nyandeni	12
	Mgojweni	3		9
	Lujizweni	2		3
	Godzi	3	Mhlontlo	14
	Gungqwana	3		10
	Mbinja	1		2
	Mazizini	2	Port St. Johns	4
	Goqwana	1		1
Sarah Baartman	Pearston	1	Blue Crane	13
	Aberdeen	1	Dr Beyers	18
	Graaf Reinet	1		11

	Bhishibha	1	Sunday's River Valley	5
	Tanki	1	Makana	20
	Wynek	1		17
Amathole	Qeto	1	Nqushwa	19
	Nyaniso	1		4
	Ndabakazi	3	Mnquma	52
	High Hill	1		7
	Gwiligwili	2	Amahlathi	28
	Kie Road	8		67
	Shinira	1	Mbashe	2
	Xuba	6		49
	Total: 71	**158**		**1007**

Appendix 10: Cross-HI test results for ND ELISA positive samples

Sample	Genotype VII antigen (virulent field strain) Log_2 HI titre	Genotype II antigen (avirulent vaccine) Log_2 HI titre
CDA1	9	10
CDA6	8	10
CDA7	7	9
CBA13	0	2
CBA16	2	3
CDC2	8	9
CDC14	5	6
YAA18	6	7
YAA19	5	7
YAA31	6	7
IBC10	2	4
IBA9	3	3
GBA2	7	9
EAD2	6	6
FAB3	5	6
GAA5	6	8
OCB2	6	7
OBA3	0	5
OAA2	6	6

PAA11	7	8
TAA10	2	4
UAA10	5	6
NAB1	0	2
LCA2	10	12
NBA1	7	8
KCB1	3	5
WBA3	7	8
WAA15	8	8
UBA11	2	3
BBB1	7	7
CAA1	4	4
ACA4	9	10
BCD1	1	2
AAC2	6	8
JAA6	6	7
KAB2	8	10
HAA8	1	2
GCB1	1	1

Appendix 11: HI Test results (Log_2 titre) for ELISA AI positive samples

Sample number	H5N1 antigen	H5N2 antigen	H5N6 antigen	H5N8 antigen	H6N2 antigen	H6N8 antigen	H7N1 antigen	H7N7 antigen
ADA1	0	7	0	0	11	9	0	0
AFB18	0	0	0	0	0	0	0	0
AFC11	0	0	0	0	0	0	0	0
AFD11	0	0	0	0	0	0	0	0
AFE6	0	0	0	0	0	0	0	0
CAA1	0	2	3	0	6	4	0	0
HAA5	0	3	2	0	9	9	0	0
HCA1	0	3	1	0	9	7	0	0
ICA1	0	4	3	0	7	7	0	0
ICB2	0	2	0	0	4	5	0	0
PAA2	0	4	2	0	8	8	0	0
PAA4	0	3	1	0	7	5	0	0
PAA9	0	3	1	0	11	7	0	0
PAA10	0	4	2	0	9	5	0	0

Appendix 12: Number of pigs sampled in each village per local municipality and per District during the survey in the ECP (August 2019-May 2020).

District	Village's name	Number of pig farmer	Local Municipality	Number of pigs sampled
Chris Hani	Bengu	3	Emalahleni	7
	Machubeni	2		5
	Mtsheko	5		9
	Lady Frere	1		5
	Tsazo	4	Ngcobo	9
	Beyele	3		8
	Khalinyanga	4		10
	All Saints	1		3
	Tshamazimba	4	Intsika Yethu	10
	Woodhouse	4		7
	Deckert's Hill	2		8
	Tsengiwe	5	Sakhisizwe	7
	Upper Indwana	2		7
	Stokwe's basin	6		7
	Machibini	6	Enoch Mgijima	8
	Zola	4		8
	Tambo	3		7
	Cradock	3	Inxuba Yethemba	22

Alfred Ndzo	Ramatli	2	Matatiele	7
	Nchodu	4		9
	Zwelitsha	3		8
	Nomlacu	4	Mbizana	8
	Nikwe	3		8
	Nkantolo	5		7
	Yandlala	2	Ntabankulu	6
	Dambeni	4		5
	Mpisini	2		9
	Goso	3	Umzimvubu	34
	Saphukanduku	2		6
	Rode	2		19
Joe Gqabi	Mzamomhle	2	Walter Sisulu	9
	Maize field	2		6
	Joe Gqabi	2		9
	Mogesi	2	Senqu	7
	New Rest	2		6
	Zava	7		10
	Ezingonyameni	3	Elundini	7
	Luzi	1		2
Metropolitan	Qalashe	3	Buffalo City	21
	Restini	2		5
	Synery Park	1		2

OR Tambo	Kambi	6	KSD	11
	Nkalane			
	Mqanduli	3		14
	Bala	7	Ingquza Hill	12
	Malangeni			
	Mhlanga	3		7
	Moyeni	3	Nyandeni	7
	Mgojweni	1		2
	Lujizweni	2		8
	Godzi	2	Mhlontlo	17
	Gungqwana	3		10
	Mbinja	2		4
	Mazizini	2	Port St. Johns	3
	Goqwana	1		7
	Sandlulube	1		5
Sarah	Pearston	1	Blue Crane	21
Baartman	Kroonstaad	2		14
	Marselle	1	Ndlambe	40
	Old Station	3		24
	Vessel Park	6		13
	7 Fountains	1	Makana	20
	Sunny Side	4		48

	Graaf Reinet	1	Dr Beyers	38
	Aberdeen	1		34
	Mosses Mabida	3	Sunday's River	67
	Nomathamsanqa	2	Valley	22
	Bhishibha	1		8
Nelson Mandela Bay	Motherwell	2		15
	Allence Refill	1		6
Amathole	Qeto	6	Nqushwa	32
	Nyaniso	1		14
	Celetyuma	3		4
	Ndabakazi	3	Mnquma	17
	High Hill	5		10
	Tika	4		7
	Mission	7		14
	Ngcisninde	2		4
	Manqulo	1		1
	Qeqe	6	Mbashe	31
	Nywarha	4		15
	Gwiligwili	6	Amahlathi	11
	Kie Road	1		6
	Total:	**239**		**1000**

Appendix 13: Biosecurity measures recommended to prevent common transmission routes based on the authors' experience and knowledge of the disease transmission (Penrith et al., 2021).

Source and transmission	**Preventive measures**
Direct contact with infected pigs	Confine pigs in pig-proof pens Acquire new pigs only from known safe sources Quarantine and observe new pigs for at least 15 days Separate any pigs showing clinical signs
Ingestion of infected material	Do not feed swill containing meat Heat swill to destroy the virus Do not allow pigs to scavenge (confine pigs in pig-proof pens) Safe disposal of infected material (carcasses, slaughter waste)
Contact with fomites	Limit access to the pigs (carers and health service providers only) Provide a change of footwear Disinfectant footbaths (effective product and brush for cleaning) Do not share equipment or clean thoroughly and disinfect before use Do not accept leftover feed or bedding from producers whose pigs have died Check vegetation supplied as feed for visible signs of contamination
Biological tick vector from warthogs	Confine pigs in pig-proof premises (to keep pigs in and warthogs out)
Biological tick vector in domestic pigs	House pigs in concrete pens with smooth finish
Stable flies	Remove breeding places (grass cuttings, discarded bedding) Use commercial fly control products

Appendix 14: Monthly and annual frequency of chicken products produced and trade undertaken in the ECP (February to June 2019).

Municipality	No. of farmers	Frequency		Not selling	Live chicken (n)	Products	
		Monthly	Yearly			Carcass (kg)	Eggs (n)
Amahlathi	6	1	5	0	292	126	0
Bizana	8	1	2	5	672	0	0
Blue Crane	3	0	0	3	0	0	0
Buffalo City	4	2	1	1	201	0	360
Dr Beyers	1	1	0	0	700	0	0
Elundini	10	1	1	8	574	0	0
Emalahleni	13	1	4	8	125	16	108000
E. Mgijima	10	0	3	7	183	0	0
Ingquza Hill	8	0	0	8	0	0	0
Intsika Yethu	12	2	4	6	196	12	2935
I. Yethemba	4	1	1	2	82	0	750
KSD	8	0	4	4	363	0	0
Makana	4	4	0	0	1140	448	192
Matatiele	8	0	4	4	93	77	0
Mbashe	6	1	1	4	294	0	0
Mhlontlo	9	1	4	4	506	0	0
Mnquma	8	1	3	4	115	148	80
Ndlambe	2	2	0	0	365	0	0

NMB	1	1	0	0	0	196	0
Ngcobo	8	0	2	6	7	0	0
Ngqushwa	4	1	1	2	4212	45	13500
Nyandeni	9	1	6	2	288	0	54
PSJ	7	0	0	7	0	0	0
Sakhisizwe	20	3	5	12	724	0	24
Senqu	11	0	7	4	197	27	90
S. Rivers	1	1	0	0	230	20	0
Tabankunlu	11	2	4	5	591	0	0
Umzimvubu	10	4	4	2	1339	80	2520
W. Sisulu	4	0	2	2	3	0	30
Total	210	32	68	110	13492	1195	128535
Percentages	100	15.2*	32.4**	52.4***			

*Percentage of farmers who were selling chickens or chicken products on a regular basis

** Percentage of farmers who were not selling chickens (or products) on a regular basis

***Percentage of farmers who were not involved in trade.

Appendix 15: Net profit margin for twelve ECP egg producers from November 2020 to July 2021

No. of point of lay hens	Total cost[1]	Total cost of feed per year[2]	Total cost of remedies	Av. annual egg production[3]	Total income per year[4]	Annual net profit	Net profit margin
300	R25500	R127750	R1000	109500	R219000	R64750	**29.57%**

[1] The average cost of one layer was calculated at R85 each.

[2] The average cost of feed was calculated at R350 per bag. The average feed intake per day was one bag (50kg)

[3] It was assumed that one layer was giving a minimum of one egg per day.

[4] The average selling price of one egg was calculated at R2.

1 South African Rand= 0.067 US Dollars

Appendix 16: Net profit margin for different restaurants (processors) in the EC major towns, on a weekly basis from November 2020 to July 2021

No of restaurants	No of chickens used per week	Cost of live chicken	Total cost of live chicken	Cost per plate	No of plates sold per week	Total income	Weekly profit	Net profit margin
1	6	R100	R600	R40	60	R2400	R1106.5	46.1%
2	15	R115	R1725	R30	120	R3600	R1181.5	32.8%
3	24	R150	R3600	R53	180	R9540	R5246.5	54.9%
4	12	R120	R1440	R40	108	R4320	R2186.5	50.6%
5	6	R120	R720	R35	48	R1680	R266.5	15.9%
6	20	R80	R1600	R40	60	R2400	R106.5	4.4%

Estimated average processing cost per restaurant per week, based on the price of ingredients used for cooking: R693.5

1 South African Rand= 0.067 US Dollars

Appendix 17: Net profit margin per incubation period for three ECP traders with individual incubators from November 2020 to July 2021

Description	Quantity	Cost	(n) chicks per incubation period*	Selling price	Income	Net profit	Net profit margin**
Fertile eggs (layer)	3 boxes with 360 eggs each (1080 eggs)	R1800 per box (R5400)	972	R21 per hen	R20412		
Fertile eggs (broilers)	6 boxes with 360 eggs each (2160 eggs)	R3.78 per egg R9389.52 (15% VAT included)	1944	R10 per boiler	R19440		
Petrol (transport)	-	R1400	-				

Main power	-	R3000	-			
Dividing boxes	100	R2700	-			
Medication	-	R260	-			
Electricity	-	R4000 for the whole incubation period				
Petrol for incubator	-	R500				
Total		R26649.52		R39852	R13202.48	**33.13%**

*The average mortality rate of 10% was considered for both broilers and layers

**Net profit margin: $\frac{Net\ profit}{Total\ revenue} \times 100$

1 South African Rand= 0.067 US Dollars

Appendix 18: Monthly and annual frequency of live pigs and pig products produced, and trade undertaken in the ECP during the initial survey conducted from February to June 2019.

Municipality	No. of farmers	Frequency		Not selling	Live pig (n)	Products
		Every 6 months	Yearly			Carcass (kg)
Amahlathi	6	1	3	2	3	505
Bizana	7	1	2	4	23	80
Blue Crane	4	1	3	0	6	30480
Buffalo City	4	2	1	1	3	160
Dr Beyers	5	3	0	2	11	2190
Elundini	5	1	1	3	10	110
Emalahleni	11	2	3	6	4	80
E. Mgijima	14	0	8	6	15	513
Ingquza Hill	6	1	2	3	4	0
Intsika Yethu	11	1	5	5	11	168
I. Yethemba	5	0	5	0	11	80
KSD	8	1	5	2	6	115
Makana	6	1	4	1	8	3575
Matatiele	7	1	4	2	20	430
Mbashe	8	1	4	3	10	0
Mhlontlo	7	0	3	4	3	360
Mnquma	8	0	2	6	5	0
Ndlambe	8	4	2	2	10	320
NMB	4	4	0	0	8	2110
Ngcobo	11	1	8	2	6	380
Ngqushwa	7	1	3	3	7	170

Nyandeni	4	0	4	0	6	0
PSJ	9	1	4	4	7	50
Sakhisizwe	10	1	5	4	16	400
Senqu	9	0	7	2	5	360
S. Rivers	9	2	7	0	16	3445
Tabankunlu	7	1	3	3	20	484
Umzimvubu	4	1	0	3	42	200
W. Sisulu	10	1	5	4	7	105
Total	214	34	103	77	303	46870
Percentages	100	15.9*	48.1**	36***		

*Percentage of farmers who were selling pigs or pig products on a regular basis

** Percentage of farmers who were not selling pigs (or pig products) on a regular basis

***Percentage of farmers who were not involved in trade.

Appendix 19: Net profit margin per pig sold according to the producers interviewed from the group “umbuto”.

Number of farmers	Average cost of feed per pig to reach 80 kg of bodyweight in 6 months	Cost of medication	Selling price per kg	Selling price per pig	Net profit	Net Profit Margin*
1	R1500	R500	R130	R10400	R8400	80.8%
2	R1500	R150	R80	R6400	R4750	74.2%
3	R1500	R180	R125	R10000	R8320	83.2%
4	R1500	R80	R75	R6000	R4420	73.7%

*Net profit margin: $\frac{Net\ profit}{Total\ revenue} \times 100$

1 South African Rand= 0.055 US Dollars

Appendix 20: Net profit margin per pig sold according to the meat traders.

Number of meat traders	Average cost of live pig	Selling price per kg	Total revenue	Net profit	Net Profit Margin*
1	R2300	R50	R4000	R1700	42.5%
2	R1500	R50	R4000	R2500	62.5%
3	R2000	R60	R4800	R2800	58.3%

*Net profit margin: $\frac{Net\ profit}{Total\ revenue} \times 100$

1 South African Rand= 0.055 US Dollars

Appendix 21: Net profit margin of pig meat according to the supermarkets and butcheries

Number of supermarkets and butcheries	Average buying price per kg from abattoir	Average selling price per kg	Net profit per kg	Net Profit Margin*
23	R25.5	R79.99	R54.49	68.12%

*Net profit margin: $\frac{Net\ profit}{Total\ revenue} \times 100$

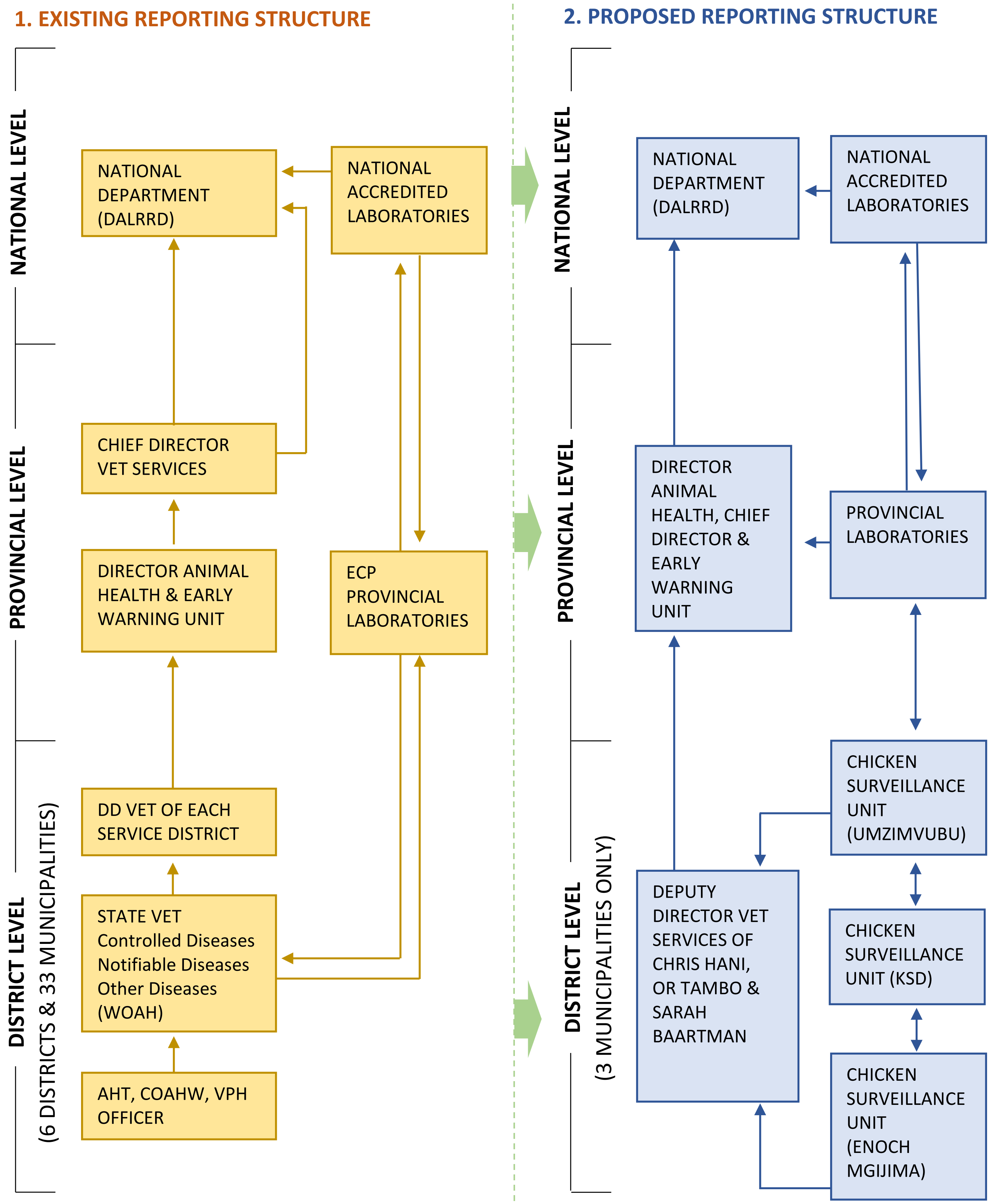
1 South African Rand= 0.055 US Dollars

Appendix 22: Net profit margin according to the processors (restaurants, tshisanyama or grills)

Number of processors	Average buying price per kg from abattoir-average buying price per kg from informal market	Average selling price per kg	Net profit per kg	Net Profit Margin*
16	R25.5-R18.75	R77.5	R52-R58.75	67.1%-75.81%

*Net profit margin: $\frac{Net\ profit}{Total\ revenue} \times 100$

1 South African Rand= 0.055 US Dollars



Appendix 23: The existing reporting structure and a proposed reporting structure targeting surveillance at hotpots in the ECP

Appendix 24: Conference presentations

Simbizi, V., Moerane, R., Ramsay, G., Mubamba, C., Abolnik, C., Gummow, B. 2021. Village chickens as a source of antimicrobial resistance and emerging diseases: a South African case study. Science Week ANZCVS 8-10 July 2021.

Simbizi, V., Moerane, R., Ramsay, G., Mubamba, C., Abolnik, C., Gummow, B. 2021. Village chickens as a source of antimicrobial resistance and emerging diseases: a South African case study. 18th Annual Congress of the Southern African Society for Veterinary Epidemiology and Preventive Medicine (SASVEPM) 25-27 August 2021 | Warmbaths Forever Resort, Bela-Bela, Limpopo.

Simbizi, V., Moerane, R., Ramsay, G., Mubamba, C., Abolnik, C., Gummow, B. 2022. Ensembling value chain and trade networks as a basis for cost-effective surveillance in rural chickens in the Eastern Cape Province of South Africa. 19th Annual SASVEPM Congress held at East London International Convention Centre from the 24th to the 26th of August 2022

Simbizi, V., Moerane, R., Ramsay, G., Mubamba, C., Abolnik, C., Gummow, B. 2022. Ensembling value chain and trade networks as a basis for cost-effective surveillance in rural chickens in the Eastern Cape Province of South Africa. 16th International Symposium of Veterinary Epidemiology and Economics from the 7th to 12th August 2022 at Halifax, Canada.

Appendix 25: Questionnaires

FARMER SURVEY

INFORMED CONSENT FORM

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
PROJECT TITLE:	**Investigating pig and poultry trade networks and farming practices in the Eastern Cape Province as a basis for surveillance**
INSTITUTIONS:	**Department of Rural Development and Agrarian Reform** Eastern Cape Provincial Government SOUTH AFRICA **Discipline of Veterinary Sciences, College of Public Health, Medical and Veterinary Sciences** James Cook University AUSTRALIA **Department of Production Animal Studies** University of Pretoria SOUTH AFRICA

I understand that the aim of this study is to describe pig movements, trading and farming practices and to understand how these activities influence the potential spread of diseases in the Eastern Cape Province.

I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written information sheet to keep.

I understand that my participation will involve a **questionnaire-based interview** and I agree that the researcher may use the results as described in the information sheet.

I acknowledge that:

- taking part in this study is voluntary and I am aware that I can stop taking part in it at any time without explanation or prejudice and to withdraw any unprocessed data I have provided;

- that any information I give will be kept strictly confidential and that no names will be used to identify me with this study without my approval;

(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Survey on pig trade networks and farming practices in the Eastern Cape Province.

Date of the survey:			
District		**Veterinary area or municipality**	
Interviewer's name: *(Capital letters)*			
Contact details:	**Telephone:** **Email:**		

The survey questionnaire below is divided into 6 parts:

(A) Personal information

(B) Farm structure and Feeding

(C) Finances

(D)Trading practices

(E) Contact with warthogs or bush pigs

(F) Pig diseases

A. Personal information

Questions
Q1- Name of the farmer? *(Capital letters)*
Q2- Gender & age of the farmer? ☐Male ☐Female ☐ Age

Q3 - Telephone contact of the farmer?
Q4- Locality of the farm? *(Capital letters)* District: Municipality: Village:
Q5 – Please record the GPS coordinates of the farm/Village:
Q6 - Please detail the residential address of the farmer if it is different from the farm locality: Municipality: Block: Street: Village:
Q7 - For how many years has the interviewee been a pig farmer?
Q8- What is the highest level of education of the farmer? ☐ No formal education ☐ Primary level ☐ High school ☐ Tertiary (if Tertiary, is Agriculture related or not), please detail:

B. **Farm Structure and Feeding**

Questions (Please fill in or cross ☒ where appropriate)
Q9- Do you keep pigs? ☐ **Yes** ☐ **No**
Q10 - What are the other livestock species kept on this farm? **(**Cross ☒ where appropriate) ☐ **Poultry**, please give the total number: ☐ **Cattle,** please give the total number: ☐ **Goats**, please give the total number: ☐ **Sheep**, please give the total number: ☐ **Donkeys**, please give the total number: ☐ **Dogs**, please give the total number: ☐ **Cats**, please give the total number: ☐ **Other**, please detail and give total number:
Q11- What type of pigs are kept on the farm? Please detail for each species: ☐ Native breed ☐ European breed ☐ Mixed breed ☐ Other (Please detail): ☐ I don't know

Q12- Please indicate how many pigs are in each category?

CATEGORY (BREED)	**PIGLETS**	**GILTS**	**SOWS**	**BOARS**	**TOTAL**
Native					
European					
Mixed					
Others					
TOTAL					

Q13- Please indicate the farm raising system?

☐ Free range farming (with pigs allowed to wander around the village)

☐ Traditional /Semi-intensive farming (with pigs confined sometimes e.g., in a pen)

☐ Large scale / Intensive farming (with pigs always kept in a confined area)

☐ Other (Please detail):

Q14- Do your pigs meet animals from other farms?

☐ No

☐ If yes, what other species of animals do they come into contact with?

- Dogs
- Pigs
- Poultry
- Sheep

Other:

Q15- What are your pigs fed?

☐ Commercial feed product (please detail the name of the feed and where it was purchased):

☐ Kitchen/Restaurant waste (swill)

☐ other:

Q16- If swill is fed, what is comprised of? ☐ Only plant material ☐ Meat ☐ other (specify)
Q17- Is swill heat treated before being fed? ☐ No ☐ If yes, how and for how long?

C. Finances

Q18- How much do you spend in total on your pigs per month?

CATEGORY (BREED)	INITIAL STOCK	HOUSING	FEED	FAMILY LABOUR	HIRED LABOUR	VET VACCINES/ DRUGS	OTHERS	TOTALS
Native								
European								
Mixed								
Others								
TOTAL								

Any comments:

Q19- How do you generally use your pigs?

☐ For selling (please detail if you sell live pig, pig product or both)

☐ For breeding

☐ For breeding and selling

☐ For own human consumption

☐ For gifts

☐ Other (please detail)

Q20- How many of your pigs does your family eat per year?

☐ Numbers

Q21- Do you sell your pigs and their products?

☐ Yes ☐ No

If the answer above is yes, please fill the number of pigs and quantity of product sold in each category in the previous 12 months in the table below

CATEGORY (BREED)	PIGLETS (n)	GILTS (n)	SOWS (n)	BOARS (n)	MEAT (Kg)	MANURE (kg)
Native						
European						
Mixed						
Others						

Q22- Do you know how much money you get from selling your pigs and their products in Rand per year?

☐ Yes ☐ No

If the answer to the above question is yes, please fill in the table below.

CATEGORY (BREED)	LIVE PIG (n)	PRODUCT (kg)	Amount in Rand
Native			
European			
Mixed			
Others			
TOTAL			

Q23- What percentage of your total household income comes from your pigs?

Please place a cross in the appropriate box.

PERCENTAGE	10	20	30	40	50	60	70	80	90	100

D. Trading practices

ON-FARM MOVEMENTS
LIVE PIGS

Q24- During the previous 12 months, did you have any new live pigs entering your farm?

☐ **No,** go to question 25.

☐ **Yes,** please detail in the table below for <u>each time</u> new pigs were entering the farm:

- **Month of entry:** detail when the new pigs were entering your farm.
- **Category of pigs:** piglets, gilts, sows, etc.
- **Origin of pigs:** Please detail where these live pigs were coming from: i.e., Commercial farm, market, another village farmer, other (specify).
- **<u>Location:</u>** detail where these new pigs were coming from (give Province and Municipality).
- **Number of new pigs:** total number of new pigs entering the farm.

Month of entry	Category of pigs	Origin of pigs	Location (important field)	Number of new pigs entering the farm

Additional comment (if required):
Q25- Did you use a middleman for purchasing and bringing these new pigs into your farm? ☐ **No** ☐ **Yes,** please detail where this middleman is based (Province, Municipality):

The objective of this section is to describe the type and the period (month) of **live pig and pig product movements to the farm** (section "on-farm movements") **and from the farm** (section "off-farm movements").

PIG PRODUCTS
Q26 - During the previous 12 months, did you bring any of the following pig products into your farm? Please cross ☒ where appropriate: - Carcass: .... ☐ No ☐ Yes - Blood: ....☐ No ☐ Yes - Offal (organs such as liver, kidney, heart...): ... ☐ No ☐ Yes - Bones: ....☐ No ☐ Yes - Swill (restaurant left over):............................. ☐ No ☐ Yes - Skin: .... ☐ No ☐ Yes - Waste meat from butcher /slaughterhouse: .....☐ No ☐ Yes - Manure ...... ☐ No ☐ Yes - Meat and bone meal: .... ☐ No ☐ Yes - **Other**, please detail: **If you crossed ☒ Yes for any of the pig products above, please give details in the table below:** - **Month of entry:** detail when these products were brought into your farm? - **Type of product:** as ticked in boxes above (e.g., carcass, offal ...)

- **Origin:** Please detail where these pig products were coming from (e.g., abattoir, market, farmer...)
- **Location:** Detail the location where these pig products were coming from (Province and Municipality).
- **Quantities of pig products:** Total number of pig products entering the farm (e.g.: 10kg of swill ...)

Month of entry	Type of product	Origin of product	Location (Important field)	Quantities of product (give units)

Q27- Did you use a middleman for purchasing and bringing these pig products into your farm?

☐ **No**

☐ **Yes,** please detail where this middleman is based (Province, Municipality):

OFF-FARM MOVEMENTS
LIVE PIG

Q28 - During the previous 12 months, did you sell or give any live pig from your farm?

☐ **No,** go to question 29.

☐ **Yes,** please give details in the table below for <u>each time</u> animals were sold or given:

- **Month of selling:** detail when pigs left your farm.
- **Category of pigs:** e.g., piglets, gilts, sows, etc.
- **Destination:** Please detail where these pigs were sent to (e.g., Abattoir, slaughterhouse, market, farm...),
- **Location:** Detail the location where these pigs were sent to (precise the Province and Municipality),
- **Number of pigs:** total number of pigs left the farm.

Month of selling	Category of pigs	Destination	Location (important field)	Number of pigs

Additional comment (if required):

Q29- Did you use a middleman for selling these animals from your farm?

☐ **No**

☐ **Yes,** where is this middleman based? (Please detail the location: Province, Municipality)

PIG PRODUCTS

Q30 - During the previous 12 months, did you sell or give any of the following pig products from your farm?

Please cross ☒ where appropriate:

- Carcass :.. ☐ No ☐ Yes -Blood: ....☐ No ☐ Yes
- Offal (organs such as liver, kidney, heart...): ... ☐ No ☐ Yes - Bones: ....☐ No ☐ Yes

- Meat: .... ☐ No ☐ Yes -Skin: .... ☐ No ☐ Yes
- Fat: .... ☐ No ☐ Yes -Manure :...... ☐ No ☐ Yes
- Other, please detail:

If you crossed ☒ Yes for any of the pig products above, please give details in the table below:

- **Month of selling:** detail when these products were sold and sent off your farm.
- **Category of products:** as ticked in boxes above (e.g.: carcass, offal ...)
- **Destination:** detail where these products were sent to (e.g.: butcher, market, farmer, relative/friend ...)
- **Location:** detail the location where these products were sent to (Province and Municipality)
- **Quantity of products:** total number of products sent off your farm (e.g.: 2 carcasses, 5 kg of offal...)

Month of selling	Category of products	Destination	Location (important field)	Quantity of products

<u>Additional comment (if required):</u>

Q31 – Did you use a middleman for selling these pig products from your farm?

☐ **No**

☐ **Yes,** where is this middleman based? (Please detail the location: Province and Municipality):

SEASONALITY OF TRADE

Q32 – Are there periods over the year when you sell more live pigs or pig products than usual?

☐ No

☐ Yes, please detail the period of the year and the associated occasion if any:

(e.g.: increased trade of pigs for the "Wedding season"; increased trade of pigs late December –early January for Christmas...)

Categories of pigs or pig products (e.g.: carcass, offal etc.)	**Periods with increased trade** (e.g.: Dec-Jan; Easter...)	**Occasion** (e.g.: Christmas, Wedding...)

D. Contact with warthogs or bush pigs.

Q33- Are there warthogs or bush pigs near your farm/village? ☐**No** ☐**Yes**
Q34- Does any of your pigs share a common habitat (ex: water source, feeding point etc.) ☐**No** ☐**Yes**
Q35- If any of your answers in question 33 and 34 was yes, please give details of the warthogs or bush pigs? **-** **-** **-** **-** **-** **-** **-** **-** **-** **-**

E. Pig diseases

Q36 - Based on your knowledge and experience, what are the diseases you most frequently see on your farm? *If the farmer doesn't know the name of the disease, write down the signs of diseases or syndromes observed on animals.*

☐ Lameness ☐ Nasal discharge and difficult breathing

☐ Loss of weight ☐ Skin condition (scab, abscess, etc.)

☐ Sudden death ☐ Other (please detail)

Q37- What measures do you implement for preventing OR controlling diseases on your farm? Please detail the nature of the measures: (in case of vaccination programme, please detail for which diseases).

-

-

-

Q38- What treatment do you commonly use to treat diseases in your pigs?

Condition	Treatment

Q39- Which disease did you see in the previous 12 months? *If the farmer doesn't know the name of the disease, write down the signs observed.*

☐ None

☐ Yes, please detail.

Disease	Month	Diagnosis (confirmed)		If yes by who?
		YES	NO	

Q40- Based on your knowledge and experience, which diseases have been occurring in pigs in your village or in the neighbouring villages in the previous 12 months? *If the farmer doesn't know the disease name, write down the signs observed.*

☐ No

☐ Yes, please detail:

-

-

-

-

-

Q41- When your pigs are sick or present abnormal signs, who do you contact for assistance?

☐ You never ask assistance to anyone.

☐ Another experienced farmer:

☐ Community /village chief:

☐ State veterinarian, please detail his/her location:

☐ Animal health technician, please detail his/her location:

☐ Extension officer, please detail his/her location:

☐ Other (please detail):

Q42– During the previous 12 months, did you find any dead pigs on your farm?

☐ No

☐ Yes, please detail the approximate total number of dead animals in the table below:

CATEGORY (BREED)	PIGLETS	GILTS	SOWS	BOARS	TOTAL
Native					
European					
Mixed					
Others					
TOTAL					

Q43– Usually, what do you do with the carcasses / dead bodies? (Cross ☒ where appropriate)

☐ Burn ☐ Family consumes ☐ Feed to dog.

☐ Sell to others ☐ Nothing ☐ Other, please detail:

Q44– Do you keep records for your pigs? ☐ Yes ☐ No If yes please details.

COMMENT: Please provide any additional comment or detail of relevance from the interview

ABATTOIR SURVEY

INFORMED CONSENT FORM

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
PROJECT TITLE:	**An analysis of value chain for rural pigs in the Eastern Cape Province**
INSTITUTIONS:	**Department of Rural Development and Agrarian Reform** Eastern Cape Provincial Government SOUTH AFRICA **Discipline of Veterinary Sciences, College of Public Health, Medical and Veterinary Sciences** James Cook University AUSTRALIA **Department of Production Animal Studies** University of Pretoria SOUTH AFRICA

I understand that the aim of this study is to analyse the value chain of rural pigs in the Eastern Cape Province.

I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written information sheet to keep.

I understand that my participation will involve a **questionnaire-based interview** and I agree that the researcher may use the results as described in the information sheet.

I acknowledge that:

- taking part in this study is voluntary and I am aware that I can stop taking part in it at any time without explanation or prejudice and to withdraw any unprocessed data I have provided;

- that any information I give will be kept strictly confidential and that no names will be used to identify me with this study without my approval;

(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Value Chain for rural pigs in the Eastern Cape Province

Abattoir

Name & Surname :

Contact details :

District or local municipality :

Village or Town :

Is your abattoir public or private?
……
…………..

What is your selection criteria when buying live pig from producers?
……
……
……
……

What are your challenges when buying from rural producers?
……
……
……
……
……
……

What is the percentage of pigs coming from local farmers?
……
……
……

Is the buying price the same for rural and commercial pigs? Yes ☐ No ☐

Buying price for rural pig (per Kg)	Buying price for commercial pig (per Kg)

How much are you selling your pig meat per Kg?
……

What is your profit margin per kilogram?

………

Who are you supplying your pig meat?

………

………

………

………

BUTCHERY SURVEY

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

INFORMED CONSENT FORM

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
PROJECT TITLE:	**An analysis of value chain for rural pigs in the Eastern Cape Province**
INSTITUTIONS:	**Department of Rural Development and Agrarian Reform** Eastern Cape Provincial Government SOUTH AFRICA **Discipline of Veterinary Sciences, College of Public Health, Medical and Veterinary Sciences** James Cook University AUSTRALIA **Department of Production Animal Studies** University of Pretoria SOUTH AFRICA

I understand that the aim of this study is to analyse the value chain of rural pigs in the Eastern Cape Province.

I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written information sheet to keep.

I understand that my participation will involve a **questionnaire-based interview** and I agree that the researcher may use the results as described in the information sheet.

I acknowledge that:

- taking part in this study is voluntary and I am aware that I can stop taking part in it at any time without explanation or prejudice and to withdraw any unprocessed data I have provided;

- that any information I give will be kept strictly confidential and that no names will be used to identify me with this study without my approval;

(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Value Chain for rural pigs in the Eastern Cape Province

Butchery

Name & Surname :

Contact details :

District or local municipality :

Village or Town :

Do you only buy pig meat from the abattoir or other places?

………
………
………
………
………
………

What is the percentage of pigs coming from local farmers?

………
………
………

How much are you buying your pig per carcass?

………
………
………

What is your profit margin per carcass?

………
………
………

Who are you supplying your pig meat?

………
………
………
………

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UMBUTHO SURVEY

INFORMED CONSENT FORM

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
PROJECT TITLE:	**An analysis of value chain for rural pigs in the Eastern Cape Province**
INSTITUTIONS:	**Department of Rural Development and Agrarian Reform** Eastern Cape Provincial Government SOUTH AFRICA **Discipline of Veterinary Sciences, College of Public Health, Medical and Veterinary Sciences** James Cook University AUSTRALIA **Department of Production Animal Studies** University of Pretoria SOUTH AFRICA

I understand that the aim of this study is to analyse the value chain of rural pigs in the Eastern Cape Province.

I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written information sheet to keep.

I understand that my participation will involve a **questionnaire-based interview** and I agree that the researcher may use the results as described in the information sheet.

I acknowledge that:

- taking part in this study is voluntary and I am aware that I can stop taking part in it at any time without explanation or prejudice and to withdraw any unprocessed data I have provided;

- that any information I give will be kept strictly confidential and that no names will be used to identify me with this study without my approval;

(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Value Chain for rural pigs in the Eastern Cape Province

Umbutho

Name & Surname :

Contact details :

District or local municipality :

Village or Town :

Where do you get your live pig from?

……
……
……
……
……

How much do you buy your live pig?

……
……

How often do you slaughter your pigs?

……
……
……
……
……

Who do you sell your pig meat to?

……
……
……
……
……
……

How much do you sell your pig meat?

……
……

What is your profit margin?

……

……

Do use meat inspector services before selling your slaughtered pig? Yes ☐ No ☐

Do you require a health permit to sell your pig meat? Yes ☐ No ☐

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RESTAURANTS OR PROCESSORS

INFORMED CONSENT FORM

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
PROJECT TITLE:	**An analysis of value chain for rural pigs in the Eastern Cape Province**
INSTITUTIONS:	**Department of Rural Development and Agrarian Reform** Eastern Cape Provincial Government SOUTH AFRICA **Discipline of Veterinary Sciences, College of Public Health, Medical and Veterinary Sciences** James Cook University AUSTRALIA **Department of Production Animal Studies** University of Pretoria SOUTH AFRICA

I understand that the aim of this study is to analyse the value chain of rural pigs in the Eastern Cape Province.

I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written information sheet to keep.

I understand that my participation will involve a **questionnaire-based interview** and I agree that the researcher may use the results as described in the information sheet.

I acknowledge that:

- taking part in this study is voluntary and I am aware that I can stop taking part in it at any time without explanation or prejudice and to withdraw any unprocessed data I have provided;

- that any information I give will be kept strictly confidential and that no names will be used to identify me with this study without my approval;

(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Value Chain for rural pigs in the Eastern Cape Province

Restaurants & Processors

Name & Surname :

Contact details :

District or local municipality :

Village or Town :

Where do you buy your pig meat from?

Farmers	
Abattoirs	
Butcheries	
Retailers	
Middlemen	
Traders	
Others	

Do you buy them alive? Yes ☐ No ☐

If yes, do you use meat inspector services? Yes ☐ No ☐

How much are you buying your pig meat?

……

……

How much do you sell your pig meat?

……

What is your profit margin?

………

………

MEAT TRADERS SURVEY

INFORMED CONSENT FORM

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
PROJECT TITLE:	**An analysis of value chain for rural pigs in the Eastern Cape Province**
INSTITUTIONS:	**Department of Rural Development and Agrarian Reform** Eastern Cape Provincial Government SOUTH AFRICA **Discipline of Veterinary Sciences, College of Public Health, Medical and Veterinary Sciences** James Cook University AUSTRALIA **Department of Production Animal Studies** University of Pretoria SOUTH AFRICA

I understand that the aim of this study is to analyse the value chain of rural pigs in the Eastern Cape Province.

I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written information sheet to keep.

I understand that my participation will involve a **questionnaire-based interview** and I agree that the researcher may use the results as described in the information sheet.

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- that any information I give will be kept strictly confidential and that no names will be used to identify me with this study without my approval;

(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Value Chain for rural pigs in the Eastern Cape Province

Meat traders

Name & Surname :

Contact details :

District or local municipality :

Village or Town :

Where do you get your live pig or meat from?

……
……
……
……
……

How much do you buy your live pig or meat?

……
……
……

How often do you sell your pig meat?

……
……
……
……
……

How much do you sell your pig meat? :

……
……

What is your profit margin?

……
……

Do use meat inspector services before selling your slaughtered pig? Yes ☐ No ☐

Do you require a health permit to sell your pig meat? Yes ☐ No ☐

PRODUCER SURVEY

INFORMED CONSENT FORM

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
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(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Value Chain for rural pigs in the Eastern Cape Province

Producer

Name & Surname :

Contact details :

District or local municipality :

Village or Town :

How do you sell your pigs? : Alive ☐ Slaughtered ☐

Which of the following breeds do you sell the most to the abattoir?

Breed	
Native	
Mixed	
European	

Which abattoir do you sell to?

……

How do you transport your pigs to the abattoir and what is the cost of transport?

……

……

Do you disinfect transport before and after you delivered your pigs? Yes ☐ No ☐

How much are you getting from the abattoir when you are selling your pigs?

……

……

……

In which form do you sell your slaughtered pigs?

Carcass	
Offal	
Head and Feet	

If you are not selling the above mentioned except for carcass what do you do with them?

……

How often do you sell your pigs?

Frequency	Number of pigs sold
Daily	
Weekly	
Monthly	
Yearly	

Do you have access to Veterinary or Extension services? Yes ☐ No ☐

If yes, which type of assistance do you get?

……

……

……

……

Do you use a middleman to sell your pigs?

……

Do you market your business? Yes ☐ No ☐

If yes, how?

……

……

……

……

……

SUPERMARKET/RETAILER SURVEY

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

INFORMED CONSENT FORM

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
PROJECT TITLE:	**An analysis of value chain for rural pigs in the Eastern Cape Province**
INSTITUTIONS:	**Department of Rural Development and Agrarian Reform** Eastern Cape Provincial Government SOUTH AFRICA **Discipline of Veterinary Sciences, College of Public Health, Medical and Veterinary Sciences** James Cook University AUSTRALIA **Department of Production Animal Studies** University of Pretoria SOUTH AFRICA

I understand that the aim of this study is to analyse the value chain of rural pigs in the Eastern Cape Province.

I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written information sheet to keep.

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- that any information I give will be kept strictly confidential and that no names will be used to identify me with this study without my approval;

(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Value chain for rural pigs in the Eastern Cape Province

Supermarket/Retailer

Name & Surname :

Contact details :

District or local municipality :

Village or Town :

Where do you get your pig meat from?:

………
………
………

How much do you buy your pig meat (price per pig/kg):

……
……

To whom do you sell your meat to?

………
………
………
………

In which form do you sell your slaughtered pig?

Carcass	
Head and Feet	
Offal	

Do use meat inspector services before selling your slaughtered pig? Yes☐ No☐

How much do you sell your pig meat (price per pig/kg)?

……
……
……

Do you require a health permit to sell your pig meat? Yes☐ No☐

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

FARMER SURVEY

INFORMED CONSENT FORM

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
PROJECT TITLE:	**Investigating pig and poultry trade networks and farming practices in the Eastern Cape Province as a basis for surveillance**
INSTITUTIONS:	**Department of Rural Development and Agrarian Reform** Eastern Cape Provincial Government SOUTH AFRICA **Discipline of Veterinary Sciences, College of Public Health, Medical and Veterinary Sciences** James Cook University AUSTRALIA **Department of Production Animal Studies** University of Pretoria SOUTH AFRICA

I understand that the aim of this study is to describe poultry movements, trading and farming practices and to understand how these activities influence the potential spread of diseases in the Eastern Cape Province.

I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written information sheet to keep.

I understand that my participation will involve a **questionnaire-based interview** and I agree that the researcher may use the results as described in the information sheet.

I acknowledge that:

- taking part in this study is voluntary and I am aware that I can stop taking part in it at any time without explanation or prejudice and to withdraw any unprocessed data I have provided;

- that any information I give will be kept strictly confidential and that no names will be used to identify me with this study without my approval;

(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Survey on poultry trade networks and farming practices in the Eastern Cape Province.

Date of the survey:			
District		**Veterinary area or municipality**	
Interviewer's name: *(Capital letters)*			
Contact details:	**Telephone:** **Email:**		

The survey questionnaire below is divided into 6 parts:

(A) Personal information

(B) Farm structure

(C) Finances

(D)Trading practices

(E) Contact with wild birds

(F) Poultry diseases

B. Personal information

Questions
Q1- Name of the farmer? *(Capital letters)*
Q2- Gender & age of the farmer? ☐Male ☐Female ☐ Age
Q3 - Telephone contact of the farmer?

Q4- Locality of the farm? *(Capital letters)* District: Municipality: Village:
Q5 – Please record the GPS coordinates of the farm/Village:
Q6 - Please detail the residential address of the farmer if it is different from the farm locality: Municipality: Block: Street: Village:
Q7 - For how many years has the interviewee been a farmer?
Q8- What is the highest level of education of the farmer?

B. **Farm Structure**

Questions (Please fill in or cross ☒ where appropriate)
Q9- Do you keep poultry? ☐ **Yes** ☐ **No**
Q10 -What are the other species kept on this farm? **(**Cross ☒ where appropriate) ☐ **Pigs**, please give the total number: ☐ **Cattle,** please give the total number: ☐ **Goats**, please give the total number: ☐ **Sheep**, please give the total number: ☐ **Donkeys**, please give the total number: ☐ **Dogs**, please give the total number: ☐ **Cats**, please give the total number: ☐ **Other**, please detail and give total number:
Q11- What type of poultry are kept on the farm? Please detail for each species: ☐ Layers ☐ Broilers ☐ Xhosa chicken ☐ Other (Please detail):
Q12- Please indicate how many birds are in each category of poultry?

CATEGORY	**CHICKS**	**PULLETS**	**COCKERELS**	**HENS**	**TOTAL**
Layers					
Broilers					
Xhosa chicken					
Others					
TOTAL					

Q13- Please indicate the farm raising system?

☐ Free range farming (with poultry allowed to wander around the village)

☐ Traditional /Semi-intensive farming (with poultry confined sometimes e.g., in a poultry house)

☐ Large scale / Intensive farming (with poultry always kept in confined area)

☐ Other (Please detail):

Q14- Do your poultry meet animals from other farms?

☐ No

☐ If yes, what other species of animals do they come into contact with?

- Dogs
- Pigs
- Poultry
- Sheep

Other:

C. Finances

Q15- How much do you spend in total on your poultry per month?

CATEGORY	INITIAL STOCK	HOUSING	FEED	FAMILY LABOUR	HIRED LABOUR	VACCINES /DRUGS	OTHERS	TOTAL
Layers								
Broiler								
Xhosa chicken								
Others								
TOTAL								

Any comments:

Q16- How many of your birds does your family eat per month?

☐ Numbers

Q17- Do you sell your poultry and their products?

☐ Yes ☐ No

If the answer above is yes, please fill the number of birds sold in each category (in the previous 12 months) in the table below.

CATEGORY	CHICKS (n)	PULLETS (n)	COCKERELS (n)	HENS (n)	ROOSTERS (n)	EGGS (n)	MANURE (kg)
Layers							
Broiler							
Xhosa chicken							
Others							

Q18- Do you know how much money you get from selling your poultry and their products in Rand per year?

☐ Yes ☐ No

If the answer to the above question is yes, please fill in the table below.

CATEGORY	Amount in Rand
Layers	
Broiler	
Xhosa chicken	
Others	
TOTAL	

Q19- What percentage of your total household income comes from your poultry?

Please place a cross in the appropriate box.

PERCENTAGE	10	20	30	40	50	60	70	80	90	100

D. Trading practices

ON-FARM MOVEMENTS

LIVE POULTRY

Q20- During the previous 12 months, did you have any new live poultry entering your farm?

☐ **No,** go to question Q22.

☐ **Yes,** please detail in the table below for <u>each time</u> new poultry were entering the flock:

- **Month of entry:** detail when the new birds were entering your farm.
- **Category of poultry:** day old chick, pullets, hens, etc.
- **Origin of poultry:** Please detail where these live birds were coming from: i.e., Commercial farm, market, commercial hatchery, other village farmer, poultry agents or other (specify).
- **<u>Location:</u>** detail where these new birds were coming from (give Province and Municipality).
- **Number of new poultry:** total number of new birds entering the flock.

Month of entry	Category of poultry	Origin of birds	<u>LOCATION</u> (important field) *(Province, Municipality)*	Number of new poultry entering the flock

Additional comment (if required):

Q21 - Did you use a middleman for purchasing and bringing these new birds into your farm?

☐ **No**

☐ **Yes,** please detail where this middleman is based (Province, Municipality):

The objective of this section is to describe the type and the period (month) of **live poultry and poultry product movements to the farm** (section "on-farm movements") **and from the farm** (section "off-farm movements").

POULTRY PRODUCTS
Q22 - During the previous 12 months, did you bring any of the following poultry products into your farm? Please cross ☒ where appropriate: - Carcass (poultry): .... ☐ No ☐ Yes - Blood:........ ☐ No ☐ Yes - Offal (organs such as liver, etc.): ………… ☐ No ☐ Yes - Bones: ... ☐ No ☐ Yes - Swill (restaurant left over……….......... ☐ No ☐ Yes - Eggs:.......... ☐ No ☐ Yes - Waste meat from butcher /slaughterhouse: ... ☐ No ☐ Yes - Skin: .. ☐ No ☐ Yes - Feathers: ……………………………………….... ☐ No ☐ Yes - Manure …… ☐ No ☐ Yes - Meat and bone meal:.................................... ☐ No ☐ Yes - **Other**, please detail: **If you crossed ☒ Yes for any of the poultry products above, please give details in the table below:** - **Month of entry:** detail when these products were brought into your farm? - **Type of product:** as ticked in boxes above (e.g., carcass, eggs ...) - **Origin:** Please detail where these poultry products were coming from (Ex: Abattoir, market, farmer, hatchery...) - <u>**Location:**</u> Detail the location where these poultry products were coming from (Province and municipality). - **Quantities of poultry products:** Total number of poultry products entering the farm (e.g.: 20 egg trays, 10kg of swill ...)

Month of entry	Type of product	Origin of product	Location (Important field)	Quantities of product (give units)

Q23- Did you use a middleman for purchasing and bringing these poultry products into your farm?

☐ **No**

☐ **Yes,** please detail where this middleman is based (Province, Municipality):

OFF-FARM MOVEMENTS
LIVE POULTRY

Q24 - During the previous 12 months, did you sell or give any live poultry from your farm?

☐ **No,** go to question Q24.

☐ **Yes,** please give details in the table below for each time animals were sold or given:

- **Month of selling:** detail when poultry left your farm.
- **Category of poultry:** e.g., day old chick, pullets, hens, etc.
- **Destination:** Please detail where these birds were sent to (e.g., Abattoir, slaughter house, market, farm...),
- **Location:** Detail the location where these birds were sent to (precise the Province and Municipality),
- **Number of poultry:** total number of birds left the flock.

Month of selling	Category of poultry	Destination	<u>LOCATION</u> (important field)	Number of poultry

<u>Additional comment (if required):</u>

Q25- Did you use a middleman for selling these animals from your farm?

☐ **No**

☐ **Yes,** where is this middleman based? (Please detail the location: Province, Municipality)

POULTRY PRODUCTS

Q26 - During the previous 12 months, did you sell or give any of the following poultry products from your farm?

Please cross ☒ where appropriate:

- Carcass (poultry):.............................. ☐ No ☐ Yes -Blood:..........☐ No ☐ Yes
- Offal (organs such as liver, kidney, heart...): ... ☐ No ☐ Yes - Bones: ....☐ No ☐ Yes
- Meat: .... ☐ No ☐ Yes -Skin:............ ☐ No ☐ Yes
- Fat: ....☐ No ☐ Yes -Feathers: ...... ☐ No ☐ Yes
- Manure : .... ☐ No ☐ Yes
- Eggs: .... ☐ No ☐ Yes - **Other**, please detail:

If you crossed ☒ Yes for any of the poultry products above, please give details in the table below:

- **Month of selling:** detail when or how often these products were sold and sent off your farm.
- **Category of products:** as ticked in boxes above (E.g.: carcass, eggs ...)
- **Destination:** detail where these products were sent to (E.g.: butcher, market, farmer, relative/friend ...)
- **Location:** detail the location where these products were sent to (Province, Municipality)
- **Quantities of products:** total number of products sent off your farm (e.g.: 2 carcasses, 5 kg of offal...)

Month of selling	Category of products	Destination	LOCATION (important field)	Quantities of products

Additional comment (if required):

Q27 – Did you use a middleman for selling these poultry products from your farm?

☐ **No**

☐ **Yes,** where is this middleman based? (Please detail the location: Province and Municipality):

SEASONALITY OF TRADE

Q28 – Are there periods over the year when you sell more live poultry or poultry products than usual?

☐ No

☐ Yes, please detail the period of the year and the associated occasion if any:

(E.g.: increased trade of poultry for the "Wedding season"; increased trade of poultry late December –early January for Christmas...)

Categories of poultry or poultry products (E.g.: chickens, eggs etc.)	**Periods with increased trade** (E.g.: Dec-Jan; Easter...)	**Occasion** (E.g.: Christmas, Wedding...)
• •		

D. Contact with wild birds.

Q29- Are there wild birds in or near your farm/village? ☐**No** ☐**Yes**
Q30- Does any of your poultry share a common habitat (ex: water source, feeding point etc.) ☐**No** ☐**Yes**
Q31- If any of your answers in question 29 and 30 was yes, please give details of the wild birds. - - - - - - - - - -

E. Poultry diseases

Q32 - Based on your knowledge and experience, what are the diseases you most frequently see in your flock? *If the farmer doesn't know the name of the disease, write down the signs of diseases observed on animals.*

-

Q33- What measures do you implement for preventing OR controlling diseases in your flock? Please detail the nature of the measures: (in case of vaccination programme, please detail for which diseases).

-

-

-

Q34- What treatment do you commonly use to treat diseases in your birds?

Condition	Treatment

Q35- Which disease did you see in the previous 12 months? *If the farmer doesn't know the name of the disease, write down the signs observed.*

☐ None

☐ Yes, please detail.

Disease	Month	Diagnosis (confirmed)		If yes by who?
		YES	NO	

Q36- Based on your knowledge and experience, which diseases have been occurring in poultry in your village or in the neighbouring villages in the previous 12 months? *If the farmer doesn't know the disease name, write down the signs observed.*

☐ No

☐ Yes, please detail:

-

-

-

-

-

Q37- When your birds are sick or present abnormal signs, who do you contact for assistance?

☐ You never ask assistance to anyone.

☐ Another experienced farmer:

☐ Community /village chief:

☐ State veterinarian, please detail his/her location:

☐ Animal health technician, please detail his/her location:

☐ Extension officer, please detail his/her location:

☐ Other (please detail):

Q38– During the previous 12 months, did you find any dead birds among your flock?

☐ No

☐ Yes, please detail the approximate total number of dead animals in the table below:

CATEGORY	**CHICKS**	**PULLETS**	**COCKERELS**	**HENS**	**TOTAL**
Layers					
Broiler					
Xhosa chicken					
Others					
TOTAL					

Q39– Usually, what do you do with the carcasses / dead bodies? (Cross ☒ where appropriate)

☐ Burn ☐ Family consumes ☐ Feed to dog.

☐ Sell to others ☐ Nothing ☐ Other, please detail:

Q40- Do you keep records for your poultry? ☐ Yes ☐ No If yes, please give details:

COMMENT: Please provide any additional comment or detail of relevance from the interview

PRODUCER SURVEY

INFORMED CONSENT FORM

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
PROJECT TITLE:	**An analysis of value chain for rural chickens in the Eastern Cape Province**
INSTITUTIONS:	**Department of Rural Development and Agrarian Reform** Eastern Cape Provincial Government SOUTH AFRICA **Discipline of Veterinary Sciences, College of Public Health, Medical and Veterinary Sciences** James Cook University AUSTRALIA **Department of Production Animal Studies** University of Pretoria SOUTH AFRICA

I understand that the aim of this study is to analyse the value chain of rural chickens in the Eastern Cape Province.

I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written information sheet to keep.

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(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Value Chain for Indigenous chickens in the Eastern Cape Province

Producer

Name & Surname :

Contact details :

District or local municipality :

Village or Town :

Flock size :

Do you keep records : Yes ☐ No ☐

Chicken type

Chicks	Hens	Cocks

Which raising system do you use?

Free Range	
Semi intensive	
Intensive	

How do you sell your chicken? : Alive ☐ Slaughtered ☐

In which form do you sell your slaughtered chicken?

Carcass	
Gizzard	
Livers	
Head and Feet	
Intestines	

If you are not selling the above mentioned except for carcass, what do you do with them?

………
………

To whom do you sell your chicken? :

………
………
………
………

Reason for selling?:

………
………
………
………

How often do you sell your chicken?

frequency	Number of chickens sold
Daily	
Weekly	
Monthly	

Do you eat your chickens?

………
………

Do you have access to Veterinary or Extension services? Yes ☐ No ☐
If yes, how which type of assistance do you get?

………
………
………

Do you use a middleman to sell your chicken?

………
………

Do you market your business? Yes ☐ No ☐
If yes, how?

………
………

Mortality rate in the previous 12 months

Mortality	Total
Chicks	
Hens	
Cocks	

Which symptoms did you see?:

……
……
……
……
……

What do you use to treat or prevent diseases in your flock?

……
……
……
……

How much do you spend on your chickens per month?

Expenses	Total
Feed	
Medicines	

Are you using any modern technology to improve productivity?

……
……
……

Do you intend to improve your flock through breeding programs?

……
……

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UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

TRADER SURVEY

INFORMED CONSENT FORM

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
PROJECT TITLE:	**An analysis of value chain for rural chickens in the Eastern Cape Province**
INSTITUTIONS:	**Department of Rural Development and Agrarian Reform** Eastern Cape Provincial Government SOUTH AFRICA **Discipline of Veterinary Sciences, College of Public Health, Medical and Veterinary Sciences** James Cook University AUSTRALIA **Department of Production Animal Studies** University of Pretoria SOUTH AFRICA

I understand that the aim of this study is to analyse the value chain of rural chickens in the Eastern Cape Province.

I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written information sheet to keep.

I understand that my participation will involve a **questionnaire-based interview** and I agree that the researcher may use the results as described in the information sheet.

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- that any information I give will be kept strictly confidential and that no names will be used to identify me with this study without my approval;

(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Value Chain for rural chickens in the Eastern Cape Province

Trader

Name & Surname :

Contact details :

District or local municipality :

Village or Town :

Number of chickens bought :

Where do you get your live chicken from?

……
……
……

How much do you buy your live chicken?

……
……

To whom do you sell your chicken?

……
……
……
……
……

Which type of chicken are you selling : Live ☐ Slaughtered ☐

If it is slaughtered how much do you sell your carcass?

……
……

In which form do you sell your slaughtered chicken?

Carcass	
Gizzard	
Livers	
Head and Feet	
Intestines	

Do you use meat inspector services before selling your slaughtered chicken?

Yes ☐ No ☐

How much do you sell your live poultry?

……

……

Do you require a health permit to sell your live chicken? Yes ☐ No ☐

Frequency of selling and quantity

Daily	Weekly	Monthly

Once your daily stock is not finished, what do you do?

……

……

……

……

……

Which occasion (period) do you sell more chickens?:

……

……

……

……

WHOLESALER/RETAILER SURVEY

INFORMED CONSENT FORM

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
PROJECT TITLE:	**An analysis of value chain for rural chickens in the Eastern Cape Province**
INSTITUTIONS:	**Department of Rural Development and Agrarian Reform** Eastern Cape Provincial Government SOUTH AFRICA **Discipline of Veterinary Sciences, College of Public Health, Medical and Veterinary Sciences** James Cook University AUSTRALIA **Department of Production Animal Studies** University of Pretoria SOUTH AFRICA

I understand that the aim of this study is to analyse the value chain of rural chickens in the Eastern Cape Province.

I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written information sheet to keep.

I understand that my participation will involve a **questionnaire-based interview** and I agree that the researcher may use the results as described in the information sheet.

I acknowledge that:

- taking part in this study is voluntary and I am aware that I can stop taking part in it at any time without explanation or prejudice and to withdraw any unprocessed data I have provided;

- that any information I give will be kept strictly confidential and that no names will be used to identify me with this study without my approval;

(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Value Chain for Indigenous chickens in the Eastern Cape Province

Wholesaler/Retailer

Name & Surname :

Contact details :

District or local municipality :

Village or Town :

Where do you get your chicken meat from?:
………
………
How much do you buy your chicken meat (price per chicken/kg):
………

To whom do you sell your poultry to?
………
………
………
In which form do you sell your slaughtered chicken?

Carcass	
Gizzard	
Livers	
Head and Feet	
Intestines	

Do use meat inspector services before selling your slaughtered chicken? Yes ☐ ☐
No

How much do you sell your chicken meat (price per chicken/kg)?
………
………

What is your production/marketing cost on your chicken meat?

Marketing activity	Average cost	Share to total cost
Chicken cost		
Transportation		
Market fees		
Losses in transit/storage		
Total costs		
Selling price		

Do you require a health permit to sell your chicken meat? Yes ☐ No ☐

RESTAURANTS OR PROCESSORS

INFORMED CONSENT FORM

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
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(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Value Chain for rural chickens in the Eastern Cape Province

Restaurants or Processors

Name & Surname :

Contact details :

District or local municipality :

Town :

Which type of chicken do you serve?

Where do you buy it from?

Farmers	
Retailers	
Middlemen	
Traders	
Others	

Do you buy them alive? Yes ☐ No ☐

If yes, do you use meat inspector services? Yes ☐ No ☐

What is the chicken cost?

Broiler	**Spent hen**

Which type of meat chicken do your customers prefer the most?

Broiler	
Spent hens	

What is the cost per plate for the following meals?

Plate	Price
Broiler meat with pap	
Broiler meat with samp	
Broiler meat with rice	
Spent hens meat with pap	
Spent hens meat with samp	
Spent hens meat with rice	

How many plates do you sell per day?

Broiler	Spent hens

How many chickens do you process?

Daily	Weekly	Monthly

Do you think you make profit? Yes ☐ No ☐

If yes, how much do you make per cooked chicken after your processing cost (spices, cooking oil, vegetables, electricity/gas etc.)?

Live chicken price (please use the answer above)	Average processing cost (spices, cooking oil, vegetables, electricity/gas etc.)	Selling price per chicken	Profit
B.			
S.			

HATCHERY OWNER

INFORMED CONSENT FORM

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

PRINCIPAL INVESTIGATOR:	**Vincent Simbizi (BVSc, Msc)** Contact: vsimbizi@yahoo.fr; vsimbizi@gmail.com +27824822999/+27795001865
PROJECT TITLE:	**An analysis of value chain for rural chickens in the Eastern Cape Province**
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- that any information I give will be kept strictly confidential and that no names will be used to identify me with this study without my approval;

(Please tick to indicate consent)

I consent to participate to the questionnaire-based interview	☐	**Yes**	☐	**No**

Name of the participant: *(Capital letters)*	
Signature:	**Date:**

For oral consent: I certify having read the content of this consent form to the participant and having received his/her oral consent to participate in this study. **Name of the interviewer:** *(Capital letters)*	
Signature:	**Date:**

Value chain questionnaire for rural chickens in the Eastern Cape Province

Hatchery owner

Name & Surname :

Contact details :

District or local municipality :

Village or Town :

Do you keep records : Yes ☐ No ☐

A. Layers

Flock size

Chicks	Hens	Cocks

Which raising system do you use?

Free Range	
Semi intensive	
Intensive	

Do you sell your layers? Yes ☐ No ☐

Do you sell your eggs? Yes ☐ No ☐

Where do you sell your layers or eggs? :

………

………

……

How often do you sell your layers or eggs?

Frequency	Number of layers sold	Number of eggs
Daily		
Weekly		
Monthly		

Do you have access to Veterinary or Extension services? Yes ☐ No ☐
If yes, which type of assistance do you get?
……
……
……

Do you use a middleman to sell your layers or eggs?
……

Do you market your business? Yes ☐ No ☐
If yes, how?
……
Mortality rate in the previous 12 months

Mortality	Total
Chicks	
Hens	
Cocks	

Which symptoms did you see?:
……
……
……
……

What do you use to treat or prevent diseases in your flock?
……
……
……
……

How much do you spend on your layers per month?

Expenses	Total
Feed	
Medicines	
Electricity	
Fuel for generator	
Other	

Are you using any modern technology to improve productivity?

……

……

Do you intend to improve your flock through breeding programs?

……

B. Hatchery

Where do you get your fertile eggs from?

For broilers:

……

……

For layers:

……

……

How much are you buying those fertile eggs?

……

……

To whom are you selling your one-day old chicks?

Broilers:

……

Layers:

……

Do you think you make profit on your business? Yes ☐ No ☐

If yes, please explain.

……

……

Appendix 26: Ethics approval documents

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Research Ethics Committee

14 November 2018

Dear Mr Simbizi

Project:	**Investigating pig and poultry trade networks and farming practices in the Eastern Cape Province as a basis for surveillance**
Researcher:	**V Simbizi**
Supervisor:	**Prof B Gummow**
Department:	**Production Animal Studies (Veterinary Science)**
Reference number:	**28077629 (GW20180835HS)**

Thank you for your response to the Committee's correspondence.

I have pleasure in informing you that the Research Ethics Committee formally **approved** the above study at an *ad hoc* meeting held on 14 November 2018. Data collection may therefore commence.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. Should your actual research depart significantly from the proposed research, it will be necessary to apply for a new research approval and ethical clearance.

We wish you success with the project.

Sincerely

Prof Maxi Schoeman
Deputy Dean: Postgraduate and Research Ethics
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail: PGHumanities@up.ac.za

cc: Prof B Gummow (Supervisor)

agriculture,
forestry & fisheries

Department:
Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

Directorate Animal Health, Department of Agriculture, Forestry and Fisheries
Private Bag X138, Pretoria 0001

Enquiries: Mr Herry Gololo • Tel: +27 12 319 7532 • Fax: +27 12 319 7470 • E-mail: HerryG@daff.gov.za
Reference: 12/11/1/1/8

Dr Vincent Simbizi
State Veterinary Services, Lady Frere
Department of Rural Development and Agrarian Reform
Eastern Cape
vsimbizi@yahoo.fr / Vincent.Simbizi@drdar.gov.za

Dear Dr Simbizi,

RE: Permission to do research in terms of Section 20 of the ANIMAL DISEASES ACT, 1984 (ACT NO. 35 of 1984)

Your email received on 2018-10-17, requesting permission under Section 20 of the Animal Disease Act, 1984 (Act No. 35 of 1984) to perform a research project or study, refers.

I am pleased to inform you that permission is hereby granted to perform the following research/study, with the following conditions :

Conditions:

1. This permission does not relieve the researcher of any responsibility which may be placed on him by any other act of the Republic of South Africa;
2. All potentially infectious material utilised or collected during the study is to be destroyed at the completion of the study. Records must be kept for five years for audit purposes. A dispensation application may be made to the Director Animal Health in the event that any of the above is to be stored or distributed;
3. The study is approved as per the application form dated 2018-11-12 and the correspondence thereafter. Written permission from the Director: Animal Health must be obtained prior to any deviation from the conditions approved for this study under this Section 20 permit. Please apply in writing to HerryG@daff.gov.za;

4. Study animals (chickens and pigs) can only be sampled once written consent has been obtained from the owner and permission has been granted by the local state veterinarian responsible for the area;
5. Blood, serum and swab samples may be collected from chickens in the Eastern Cape, for which a state veterinary letter has been provided and sent to the Poultry Research Unit at the University of Pretoria and/or Deltamune laboratory for testing;
6. Serum samples may be collected from pigs in the Eastern Cape, for which a state veterinary letter has been provided and sent to the ARC-Virology laboratory;
7. Specimens must be packaged and transported in accordance with International Air Transport Association (IATA) requirements and/or the National Road Traffic Act, 1996 (Act No. 93 of 1996);
8. Any samples testing suspect or positive needs to be reported to the local state veterinarian responsible for the area as well as to DAFF;
9. Chicken serum samples may be stored at the UP Poultry Research Unit and pig serum samples may be stored at the ARC-OVR, any further use of these samples are subject to obtaining Section 20 permission;
10. Ethical approval for the study must be obtained from the relevant authority before the study may start;
11. If required, an application for an extension must be made by the responsible researcher at least one month prior to the expiry of this Section 20 approval.

Title of research/study: Investigating pig and poultry trade networks and farming practices in the Eastern Cape Province as a basis of surveillance

Researcher (s): Dr Vincent Simbizi

Institution: University of Pretoria, Department of Production Animal Studies

Your Ref./ Project Number: none provided

Our ref Number: 12/11/1/1/8

Expiry date: 2021-12-31

Kind regards,

M. Maja

DR. MPHO MAJA

DIRECTOR OF ANIMAL HEALTH

Date: 2018 -11- 15

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Animal Ethics Committee

PROJECT TITLE	**Investigating pig and poultry trade networks and farming practices in the Eastern Cape Province as a basis for surveillance**
PROJECT NUMBER	**V038-18**
RESEARCHER/PRINCIPAL INVESTIGATOR	**Dr. V Simbizi**

STUDENT NUMBER (where applicable)	**U_28077629**
DISSERTATION/THESIS SUBMITTED FOR	**PhD**

ANIMAL SPECIES/SAMPLES	**Porcine**	**Avean**
NUMBER OF ANIMALS	**1000 (using 2ml serum)**	**1000 (using 2ml serum)**
Approval period to use animals for research/testing purposes	**June 2018 – June 2019**	
SUPERVISOR	**Prof. B Gummow**	

<u>KINDLY NOTE:</u>

Should there be a change in the species or number of animal/s required, or the experimental procedure/s - please submit an amendment form to the UP Animal Ethics Committee for approval before commencing with the experiment

APPROVED	Date 14 July 2018
CHAIRMAN: UP Animal Ethics Committee	Signature

S4285-15

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Research Ethics Committee

PROJECT TITLE	**Investigating pig and poultry trade networks and farming practices in the Eastern Cape Province as a basis for surveillance.**
PROJECT NUMBER	**REC109-18**
RESEARCHER/PRINCIPAL INVESTIGATOR	**Vincent Simbizi**

DISSERTATION/THESIS SUBMITTED FOR	**PhD**

SUPERVISOR	**Bruce Gummow**

APPROVED	Date **12 December 2018**
CHAIRMAN: UP Research Ethics Committee	Signature