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EFFECTS OF CLIMATIC VARIATIONS ON THE SPREAD AND OUTBREAK OF NEWCASTLE DISEASE. A CRITICAL LITERATURE REVIEW

By

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Abstract

Purpose: Poultry plays a key role in the lives of the poor rural population in developing countries. Poultry production is constrained especially among small scale farmers due to Newcastle Disease. This study aimed to investigate the underlying climatic variables and other factors that contributed to the seasonal outbreak and spread of ND. It also examined the socio-economic impacts of ND to the small scale poultry farmers and various strategies that had been put in place to manage this disease.

Methodology: The paper used a desk study review methodology where relevant empirical literature was reviewed to identify main themes and to extract knowledge gaps

Conclusion: The research concludes that there is a relationship between climate variables and ND. Poultry farmers got many benefits from keeping of free range indigenous chicken. These included income, food (eggs and meat) and also source of self-employment. From the study, it was found out that farmers use different methods to control the disease. These include use of traditional herbs such as grounded garlic mixed with water; grounded aloe mixed water, fresh milk and grounded mangoes.

Recommendations: The government should employ more extension officers and decentralize veterinary offices to the sub-location levels so as to bring services to the farmer. This will enable farmers to get technical assistance without travelling long distances. Establish quarantine system to curb the spread of the disease and also establish a slaughter house to allow inspection. This will ensure that only healthy chicken are sold to consumers among others.

Key words: *climatic variables, seasonal outbreak, socio-economic impacts, small scale poultry farmers*

1.0 INTRODUCTION

1.1 Background of the Study

Poultry plays a key role in the lives of the poor rural population in developing countries. This is especially so in Sub-Saharan Africa (SSA) where they provide income, capital assets, and fertilizers (Mottet, A., & Tempio, G. 2017). In Kenya both hybrid and indigenous poultry are reared. Indigenous poultry production presents a significant portion of the economy and a source of income to small scale farmers (Nduthu, P. W. 2015). Most farmers in rural areas rear chicken because they are raised with relatively low capital, space and readily available household labor.

They are also hardy, adapt well to the rural environments, survive on low inputs and adapt to fluctuations in the available feed resources. Chicken roam in the yard, around the boxes in the garbage in search of grain, greenery, crickets, termites, ants, insects and other feeds.

FRIC play a vital role in the improvement of the nutritional status and income of many poor rural households. They are also a global asset for many millions who live below the poverty line (Nyaiyo, N. M., & Maangi, E. N 2014). It provides scarce animal protein in form of meat, eggs and provides the owners with a form of saving which can help in times of need to meet essential family expenses such as medicines, clothing and school fees. Families also increase their income by taking advantage of seasonal peaks in poultry demand, such as at religious festivals or celebrations. Other benefits include pest control, provision of manure, contribution to traditional ceremonies and cleanliness and hygiene as FRIC feed on leftover foods.

Despite their importance, FRIC are faced by many challenges. These include: predation by snakes and birds of prey, poor housing, poor nutrition, climate variability, attack by pests and diseases and lack of adequate assistance from extension services (Nasi, R. et al 2019). Climate variability can alter poultry's relationship with parasites and vectors. These variations can influence where parasites and vectors thrive, making certain geographical regions more amenable to them. Climate can determine how vectors are distributed, transmitted and evolve and can influence the factors associated with emerging poultry diseases and how birds respond to these diseases (Sehgal, R. N. 2015).

Newcastle disease (ND), caused by Avian Paramyxovirus Type 1(APMV-1), is one of the most significant diseases for poultry producers around the world (Abdisa, T., & Tagesu, T. 2017). This poultry disease is influenced directly or indirectly by weather and climate. These may be spatial with climate affecting distribution or temporal with weather affecting timing of an outbreak and both relate to the intensity of an outbreak. Outbreaks are often associated with alternating heavy rainfall, drought and high temperatures (Moreira, R. P et al 2020). Higher temperatures may increase the rate of development of certain pathogens or parasites that have one or more life cycle outside the animal host. This may shorten generation times and possibly increase the total number of generations per year leading to higher pathogen or parasite population sizes.

The disease is widely distributed throughout the world; in 2008, 73 countries reported presence of the disease to the Office of International des Epizooties (OIE, 2009). Additionally, numerous nations in Asia, Africa, Central America, and South America have endemic or frequent outbreaks caused by virulent Newcastle Disease Virus (NDV) and there are sporadic outbreaks of the virus worldwide (OIE, 2009). ND is the most serious epizootic poultry disease in the most low income food-deficit countries (LIFDCs). It occurs every year and kills on average 70% to 80% of the unvaccinated FRIC. ND was enzootic in much of Africa and caused mortalities of all age groups from chicks to adults. Outbreaks of ND reported to World Animal Health information Database showed higher cases of ND outbreak in Ghana as compared to Kenya from 2005-2008 Boelaert, M. et al 2018)

Despite the awareness, that disease emergence may be related to ecological change few studies have vigorously analyzed environmental drivers of the dynamics of disease emergence (Riana et al., 2008). Therefore more research into causes and methods of disease control is needed not only to reduce countrywide disease prevalence, but also to combat poverty and hunger in the nation.

This in turn will enable the Government of Kenya to achieve one of its Millennium Development Goals (MDGs) of eradicating extreme hunger and poverty. The study aimed at finding out the effects of climatic variables and other factors on the seasonal variation of ND in FRIC and its socio-economic implications to the livelihoods of farmers.

1.2 Statement of the Problem

Indigenous chicken in Kenya are about 76 percent of the total poultry population and produce about 55 percent and 47 percent of the total meat and eggs respectively. Despite this contribution, poultry production is constrained especially among small scale farmers due to Newcastle Disease (ND) (Ipara, B. O et al., 2020) In Kenya, research done in the lowlands, midlands and highlands revealed that parasites are a common health problem on FRIC and agro-climate influenced their distribution (Williams, M. C. 2019). These parasites in turn cause disease on FRIC. ND is the most prevalent and fatal disease in poultry in Kenya (MOLD, 2006). This disease leads to great economic losses through deaths.

Despite the occurrence of many losses due to ND, efforts being made to address this problem are not adequate. Consequently, the study investigated the underlying climatic variables and other factors that contributed to the seasonal outbreak and spread of ND. It also examined the socio-economic impacts of ND to the small scale poultry farmers and various strategies that had been put in place to manage this disease.

1.3 Objectives of the Study

The main objective of the study was to investigate the effect of variations in climatic factors and other factors on the outbreak and spread of ND

1.4 Justification of the Study

FRIC are the dominant form of poultry kept in Kenya (Maud, C., & Rushton, J. 2018). They are a natural resource whose potential is not fully exploited for the welfare of the rural populations. Being the second priority ranking livestock enterprise, (GOK, 2009) indigenous chicken play a role in poverty alleviation. Income from the sale of eggs and live chickens help boost the family income (MOLD, 2008). Therefore, increasing the productivity of these chickens will make significant contribution towards increasing their food security and secure their livelihood. Over the years, farmers have experienced huge losses due to deaths of chicken caused by seasonal outbreaks of ND (GOK, 2009). This is because little has been done concerning disease emergence and climate in this area. In addition to this, the enterprise is gaining momentum because of scarcity of land that is caused by high population density hence many people have embarked on rearing of indigenous chicken as it requires small space (GOK, 2009)

The research provides a comprehensive and valuable technical guide for those in government or agencies who wish to embark on projects that exploit the potential of small scale poultry production to improve the livelihood of the rural poor. It will also help farmers to predict the outbreak of the disease and take early precautionary measures.

2.0 LITERATURE REVIEW

2.1 Benefits and challenges facing poultry farming

Free Range Indigenous Chicken (FRIC) are most significant livestock species in terms of the level of ownership, access to animal protein and the potential for earning income (SANDCP, 2005). In SSA, 85 percent of all households keep FRIC, with women owning 70 percent of them. Poultry provides approximately 20 percent of protein consumed in the developing countries (Mottet, A., & Tempio, G. 2017).

Free Range Indigenous Chicken play a vital role in the improvement of the nutritional status and income of many poor rural households and are a global asset for many millions who live below the poverty line (Padhi, M. K. 2016). It provides scarce animal protein in form of meat, eggs and provides the owners with a form of saving which can help in times of need to meet essential family expenses such as medicines, clothing and school fees. Families can also increase their income by taking advantage of seasonal peaks in poultry demand, such as at religious festivals or celebrations. Other benefits include pest control, provision of manure, contribution to traditional ceremonies and festivals and cleanliness and hygiene. FRIC feed on remains of foods which could have otherwise rotten and increase dirt in homesteads.

In Kenya Poultry keeping is one of the most popular livestock enterprises due to its low capital and space requirements. The poultry sector contributes about 55 percent to the livestock sector and 30 percent of the agricultural gross domestic product (GDP) or 7.8 percent of the total GDP (GOK, 2007). In the year 2006, Kenya had an estimated 37.3 million birds, of which free-range indigenous birds comprised 84.1 percent or 31.4 million birds, 8.4 percent were layers or 3.1 million birds, 5.7 percent or 2.1 million birds were broilers. Other poultry species (ducks, turkeys, pigeons, guinea fowl and quails) accounted for 1.8 percent or 0.7 million (MOLD, 2007)

Despite their importance, FRIC are faced with many constraints and challenges. These range from diseases to predators, theft, feeding, marketing, ecto and endo parasites (Habimana, R., & Kahi, A. K. 2017). The diseases affecting indigenous chicken (IC) include ND, fowl typhoid, Gumboro, coccidiosis and eye infection. ND has been singled out to be the most significant source of economic losses in IC. Direct estimation of economic losses from ND by household rounded up to a mean of seasonal loss of 40 birds per year in the coastal lowlands of Kenya. Newcastle Disease (ND) is a highly infectious viral disease caused by a paramyxovirus which mainly affects poultry. The ND virus can infect through the respiratory tract, the ocular mucous membranes and the digestive tract. The incubation period usually ranges from 2 to 15 days depending on the strain of virus. The virulence of the disease depends on the particular strain of the virus. Of the highly virulent strains, which are particularly common in South –East Asia and Africa, some grow in the gut (viscerotropic), while others grow mainly in the central nervous system (neurotropic strains). The most common indication of a serious outbreak of a neurotropic strain of the disease is seen in a nervous symptom exhibited in infected birds where neck twist right back and the chickens simply fall and die. Less virulent strains, such as those that are endemic in Australia, affect only the respiratory system, with varying degrees of severity. Symptoms may include loss of appetite, a dramatic drop in egg production, increased respiration, and coughing, gasping and even rapid death without exhibition of other symptoms.

2.2 Effects of climate on the outbreak and spread of Newcastle disease

Weather and Climate change is a phenomenon that currently can be recognized by many indicators and its impacts affect not only species and ecosystems but also human economy and society (IPCC, 2007). Newcastle poultry disease is affected directly or indirectly by weather and climate. These links may be spatial with climate affecting distribution, temporal with weather affecting timing of an outbreak or relate to the intensity of an outbreak. Outbreaks are often associated with alternating heavy rainfall, drought and high temperatures (Kebede, A., & Haile, G. (2018).

A study conducted revealed that Newcastle Disease Virus (NDV) was significantly higher (17.8 percent) in the dry hot zones compared to the cool wet zone at 9 percent showing climate as a risk factor in the occurrence of NDV in FRIC. In addition to that, the major outbreak of Newcastle disease regularly occur at the peak of the rain (June/July) and the dry season (January/February) during which mortality reaches 70 – 100% in Nigeria.

Unfortunately the period of high demand in dry season coincided with high incidence of Newcastle disease thus increasing its spread (Mubamba, C et al 2018). This high demand for FRIC in December/January for Christmas and New Year Celebrations is a major factor for its spread in Nigeria. Also a study done by Olabode et al., (2012) in Ilorin Kwara state in Nigeria revealed seasonal distribution of the disease indicated a higher occurrence in the dry season (October-March). Therefore pathogens or parasites that are sensitive to moist or dry conditions may be affected by changes in precipitation, soil moisture and frequent floods.

In relation to temperature, the virus can survive for more than 8 weeks in hot dry areas at temperatures of 40oC (Warner, 1989), for about 3 months at 20oC to 30oC and even longer at cooler temperatures (Lancaster, 1966). At 23oC -29oC, the virus (APMV-I) is reported to survive in contaminated litter for 10 to 14 days and 20oC in soil for 22 days (Institute of International Co-operation in Animal Biologics, IICAB, 2005). When temperatures are just above freezing point (1-2 oC) the virus is reported to survive on chicken skin up to 160 days and in bone marrow for nearly 200 days. APMV-1 can be inactivated by heat of 560 c for three hours or 600 c for 30 minutes (IICAB, 2005)

Airborne spread of ND was considered to be of major significance during the early outbreaks of 1970-1972 epidemics in Great Britain, but little significance is attached to airborne spread in reports from many countries (Alexander, 1988). High relative humidity and rainfall induce the outbreak of disease in poultry through the creation of a conducive breeding environment for disease pathogens (Duchenne-Moutien, R. A., & Neetoo, H. 2021). Overheating or chilling becomes a serious stress factor, which pre-disposes the bird to the disease. This brings in the climatic conditions such as the wet season when frequent rainfall affects the environment or the dry season when the temperatures may be high.

Newcastle Disease was first recognized in Indonesia in 1926 and has persisted as the major disease affecting poultry. Although little systematic research has been conducted on the epidemiology of ND in Indonesia, it is reputed to affect both indigenous and imported species of poultry throughout the country on what would appear to be a seasonal basis. Highest mortalities have been reported towards the end of the dry season for the months between July-September, the period which farmers refer to as 'musim penyakit' or the 'disease season' (Kingston and Creswell, 1982) It is

evident that climate influences the outbreak and spread of Newcastle disease, hence the need to determine its influence on FRIC.

2.3 Socio- economic impacts of Newcastle disease in poultry farmers

Newcastle Disease (ND) is an important limiting factor in the productivity of village poultry which results in great economic losses (Nnadi, P. A., Ezema, C 2021). ND occurs every year and kills on average 70% to 100% of unvaccinated FRIC in LIFDCs. In Tanzania, the mortality rate in affected flocks may reach 90 percent and the disease sometimes devastates entire flocks during outbreaks (Desta, T. T. 2021). In Kenya, ND is the most devastating disease in free range indigenous chicken (Badamana, M., & Amimo, J. O. 2015). The disease results in great economic losses which come as a result of high mortality rates.

According to Miller (2017), disease in poultry has seven main economic impacts, namely: i) reduction in the level of marketable outputs, ii) reduction in output quality, iii) waste or higher level of use of inputs, iv) resource costs associated with disease prevention and control, v) human health costs associated with disease or disease control, vi) negative animal welfare associated with disease and vii) international trade restrictions due to disease and its control. In addition, FAO (2001), considers poultry disease an example of invasive species, and categorizes six areas of their impact namely, production effects, market and price effects, trade effects, impact on food security, human health and environment and financial costs. From the above literature, it is evident that ND causes great economic losses through deaths of chicken, lowers egg production since chicken lose appetite and causes conjunctivitis to human beings. NDV is a human pathogen and most common sign of infection is conjunctivitis that develops within 24 hours of NDV exposure to the eyes (Mondal, D. 2015).).

2.4 Adaptive and mitigation measures used to manage Newcastle Disease

In order to control ND, the farmers use different approaches. Some use local treatments such as; use of " omo" washing detergent with food or water, using grounded garlic mixed with water, use of car battery water and grounding aloe put in drinking water. Aloe species is arguably the most important, as it is found in many geographical regions and is believed to be effective against a wide range of range of diseases and ailments. Shah, M. S. et al (2018) found that most poultry farmers in Western Kenya commonly use Aloe vera extracts to manage Newcastle disease.

Diseased birds and in some cases dead birds are eaten and some farmers bury the remains after eating and non-eaten chicken in pits. In addition to this, farmers sell their birds as quickly as possible when the signs of ND appear. In Uganda, birds usually die during the dry season due to disease outbreak. Therefore, most farmers start selling off their stocks just before the dry season, often when the birds are in the incubated phase of ND (Christley, R. M., & Wigley, P. 2017). Farmers also take hygiene measures such as cleaning and disinfecting of poultry houses, observing personal hygiene when handling chicken such as removing shoes when entering poultry houses and washing hands before handling chicken. Other farmers also control parasites by deworming using traditional herbs such as garlic and administering drugs such as Ascarex D (Shahardar, R. A 2017). Some farmers also vaccinate their chicken using vaccines that are available at district and divisional veterinary offices and from local agro vets.

2.5 Empirical review

Sibitali (2013), conducted a study on selected factors affecting the development of indigenous poultry value chain in Vihiga county. The value chain approach embraces the full range of activities which are required to bring a product or service from conception, through the intermediary phases of production, delivery to final consumers, and final disposal after use. Traditionally extension agents have concentrated their efforts on technology transfer that targeted production aspects of a poultry and ignored other factors of the value chain. Most farmers specialize in production and may be excluded from decision making about issues that affect them outside their farms. There exists a knowledge gap of what potential there is for income generation and employment creation in the indigenous poultry value chain. Despite their hard work farmers continue to have low incomes resulting into low living standards. There are several factors that influence the indigenous poultry value chain. This study aimed to explore how selected factors of disease control, credit, market infrastructure, and skills development affect the development of the indigenous poultry production value chain in Vihiga District. The study employed a descriptive survey research design. The target population consisted of 600 farmers who were members of 30 local poultry commercialization Common Interest Groups, 17 Agrovet attendants, 20 local poultry traders, and seven Field Extension Officers. A random sample of 103 farmers was drawn using purposive sampling method. Quota sampling was used to sample nine agrovets, and ten local poultry traders. All the seven extension staff was included in the study. The reliability coefficient for the farmers' instrument obtained was 0.87. This was considered adequate for the study. Data was analyzed using frequencies, means and multiple regression at $p = 0.05$. The results from the study showed that that reconstitution of the Newcastle vaccine and market access had statistically significant effects on the development of the indigenous poultry value chain in Vihiga District. Additionally market facilities for slaughter, cold storage and dedicated sell outlets for table birds were completely lacking in all the major market centers in the study area. Extension agents should embrace the value chain approach and provide information on marketing.

Khobondo (2018), conducted a study on the genetics and immunity of indigenous chicken in Kenya. The IC productivity is compromised by diseases that contribute to over 50% of economic losses. This study was undertaken to contribute to improved productivity of indigenous chicken (IC) of Kenya through sustainable breeding for disease tolerance and enhanced immunity by searching for appropriate probiotics. The specific objectives of the study were: 1) to determine the sources of variation of Natural antibodies (Nabs) (IgG, IgM and IgA) binding keyhole limpet hemocyanin (KLH) amongst the IC, 2) to estimate the repeatability and variation of the ELISA assay (Nabs) with time within the IC, 3) to assess the diversity and population structure of IC using LEI0258 Marker, 4) to determine the effects of probiotic on IgM titre levels on IC 5) to determine composition and diversity of microbial populations in the chickens and 6) to identify potential bacterial species for use as probiotics for enhanced immunity. Blood was drawn from the wing vein of IC and plasma separated. Natural antibodies (IgM, IgA, IgG) titer values binding KLH were determined by indirect ELISA. One way ANOVA and Mixed model analyses were used to determine sources of Nab titer variation and estimate repeatability parameter. The IC genetic diversity and population structure was achieved by DNA extraction from blood and genotyping using the MHC linked LEI0258 marker and sequencing of subset of representative alleles. Polymorphism and population genetic parameters were determined using bioinformatics tools.

Effect of commercial probiotics on IgM titer values was done by comparing treatment and control means using one factor ANOVA. Metagenomics employed usage of DNA from fecal samples and next generation sequencing. Qiime pipeline was used to call operational taxonomic units OTU) and for alpha and beta diversity analysis of microbial composition. The microbiome abundance between immune competency levels was compared using one factor ANOVA. The results of the study showed that presence and variation of Nabs amongst the IC. The variance estimate for chicken components were high and significant for IgM (p=0.003), IgG (p=0.0001) and IgA (p=0.0001).The repeatability of the ELISA assay to Nabs was high in all the immunoglobulin isotypes. Repeatability was 0.68, 0.99 and 0.99 for IgM, IgG and IgA respectively. The LEI0258 locus showed high diversity and presence of four gene pools among the IC. The locus observed high diversity as revealed by the average Shannon's information index of 2.768. The vii mean overall observed heterozygosity and Polymorphic information Content (PIC) was 0.844 and 0.932 respectively for the total population sampled. The central population had the highest observed heterozygosity (0.878) while coastal had the lowest (0.792). Use of commercial probiotic did not have significant effect on IgM titer values of IC. The metagenomics revealed extensive microbial diversity. Candidate bacterial species differed significantly for immune response level.

Muswali (2012), conducted a study on factors influencing vaccine biotechnology adoption by small- holder poultry framers in Kathiani and Central divisions of Machakos District, Kenya. Agricultural biotechnology, of which poultry vaccine production is an integral component, is believed to hold great potential for contributing significantly to household food security particularly among the small-holder farmers in developing countries such as Kenya. In view of this, developing countries are adopting agricultural biotechnology and Kenya has so far embraced various aspects of this technology including tissue culture planting materials and use of vaccines against livestock/poultry diseases. This descriptive cross-sectional study therefore sought to investigate the factors influencing adoption of the Newcastle disease vaccine, a product of agricultural biotechnology, in Kathiani and Central Division of Machakos district where the vaccine was introduced by the Kenya Agricultural Research Institute (KARI) in 1998. A sample size of 150 poultry farmers, most of them small-holder farmers, was determined. The two study areas of Kathiani and Central divisions of Machakos District were selected purposively because KARI, the sponsor of this study, needed data from these divisions for future biotechnology programming. Systematic sampling methodology was then used to identify households in each of the five locations of the two divisions from which respondents were selected and interviewed through interviewer-administered questionnaire. The results of the study showed that Newcastle disease (NCD) vaccine adoption was poor since the majority (147; 98%) of small-holder farmers interviewed could not afford it each time they wanted to vaccinate their birds. Similarly, due to limited awareness regarding the importance of vaccine use, many (123; 82%) small-holder farmers interviewed did not know of its availability in the study areas. This, in turn, resulted in the vaccine's poor adoption rates by the said farmers. The difference between the levels of awareness and unawareness of the vaccine among respondents was significant $\chi 2$ df1 = 61.440; $P < 0.001$). Only 3 (2%) of the respondents who knew about the vaccine used it. The difference between these respondents and those who did not use it (147; 98%) was also statistically significant ($\chi 2$ df1 = 138.240; $P < 0.001$). The study established that there were no distribution arrangements of the vaccine in the study area to specifically address the needs of the small-holder poultry farmers. This

too, contributed to poor adoption of the vaccine by the farmers. In conclusion, unaffordability, low awareness levels as well as lack of distribution strategies for NCD vaccine contributed to its poor adoption levels in the study area. Therefore, the biotechnology intervention (NCD vaccine) may not have contributed to significant increase in household poultry production in the area.

Ipara (2019), conducted an analysis of farmers' and traders' awareness, perceptions and effect of chicken value chain practices on Newcastle Disease outbreaks in Kenya. Newcastle disease (ND) is a major challenge affecting chicken production in Kenya. It causes mortalities of 80 to 100 percent, depriving farmers and traders of their sources of livelihood. The disease is the main challenge for farmers who rear indigenous chicken under the free-range production system. It is unclear how farmers and traders manage ND under the prevailing value chain systems due to lack of uniformity in husbandry, marketing and production practices. Farmers' and traders' awareness levels of the disease and its mitigation are relatively undefined. This leads to flaws in value chain practices, thereby increasing the frequency of disease outbreaks. Whereas evidence of control of the disease in commercial chicken is well documented, the challenge remains the control of ND in free range production systems. There exists limited information on how the chicken value chain practices influence the frequency of ND as farmers and traders manage their flocks differently. To address these gaps, this study analyzed the level of awareness, perceptions and factors influencing ND among farmers and traders as well as the effects of chicken value chain practices on the frequency of ND outbreaks in Kenya. Primary data was collected from 332 chicken rearing farmers in Kakamega and Machakos Counties as well as 336 traders in live bird markets in Kakamega, Machakos and Nairobi Counties. Descriptive statistics, the chi-square statistic, binary logit model and the Poisson regression model (PRM) were applied in the data analysis. Results showed a gender difference between chicken production and marketing activities. Chicken production was dominated by women while the marketing was dominated by men. Access to institutional support services like extension, training and credit was low among farmers and traders across the three Counties. Household type, extension, training, group membership and marital status were found to significantly influence the likelihood of chicken farmers being aware of ND. For traders, experience, group membership, age, gender and marital status were found to significantly influence the likelihood of ND awareness. The results from the study showed that practices like record keeping and market channels used to source birds had significant association with farmers' perception on ND during outbreaks. Similarly, practices like market channels used to source birds, form of birds sold, mode of transportation, origin of birds, availability of designated slaughter points, waste disposal and housing of birds were also found to have significant association with traders' perception on ND during outbreaks. From the PRM, flock size and age of birds were found to have positive effects while source of birds, form of housing, housing composition, frequency of cleaning shelter, screening of birds, mixed production system as well as farmer attributes like access to extension were found to have negative effects on the frequency of ND outbreaks among farmers. Among traders, practices like breed composition, form of birds, sale of other poultry species, use of motorcycle/ bicycle, mixing of birds, slaughter of birds and housing were found to have a positive effect while source of birds, origin of birds, disposal of waste as well as trader attributes like access to animal health training, licensing and gender had negative effects on the frequency of ND outbreaks.

2.6 Research gaps

Methodological gap is the gap that is presented as a result in limitations in the methods and techniques used in the research (explains the situation as it is, avoids bias, positivism, etc.). For instance, Muswali (2012), conducted a study on factors influencing vaccine biotechnology adoption by small- holder poultry framers in Kathiani and Central divisions of Machakos District, Kenya. The results of the study showed that Newcastle disease (NCD) vaccine adoption was poor since the majority (147; 98%) of small-holder farmers interviewed could not afford it each time they wanted to vaccinate their birds. The studies presented a methodological gap as it used exploratory and descriptive survey research design while our current study adopted a desktop literature review method.

Contextual gap arises because of the differences between the findings of different concerns of Newcastle Disease. Primary data was collected from 332 chicken rearing farmers in Kakamega and Machakos Counties as well as 336 traders in live bird markets in Kakamega, Machakos and Nairobi Counties. Descriptive statistics, the chi-square statistic, binary logit model and the Poisson regression model (PRM) were applied in the data analysis. Results showed a gender difference between chicken production and marketing activities. Chicken production was dominated by women while the marketing was dominated by men. Access to institutional support services like extension, training and credit was low among farmers and traders across the three Counties. Household type, extension, training, group membership and marital status were found to significantly influence the likelihood of chicken farmers being aware of ND. For traders, experience, group membership, age, gender and marital status were found to significantly influence the likelihood of ND awareness. A contextual gap presents itself as this study focuses on the effects of climatic variations on the spread and outbreak of Newcastle Disease.

3.0 METHODOLOGY

The study adopted a desktop literature review method (desk study). This involved an in-depth review of studies related the effects of variations in climatic factors and other factors on the outbreak and spread of ND. Three sorting stages were implemented on the subject under study in order to determine the viability of the subject for research. This is the first stage that comprised the initial identification of all articles that were based on the effects of variations in climatic factors and other factors on the outbreak and spread of ND. The search was done generally by searching the articles in the article title, abstract, keywords. A second search involved fully available publications on the subject on the effects of variations in climatic factors and other factors on the outbreak and spread of ND. The third step involved the selection of fully accessible publications. Reduction of the literature to only fully accessible publications yielded specificity and allowed the researcher to focus on the articles that related to the effects of variations in climatic factors and other factors on the outbreak and spread of ND which was split into top key words. After an in-depth search into the top key words (Newcastle disease, indigenous chicken, free range), the researcher arrived at 4 articles that were suitable for analysis.

Sibitali (2013), conducted a study on selected factors affecting the development of indigenous poultry value chain in Vihiga county. A random sample of 103 farmers was drawn using purposive sampling method. Quota sampling was used to sample nine agro vets, and ten local poultry traders. All the seven extension staff was included in the study. The reliability coefficient for the farmers'

instrument obtained was 0.87. This was considered adequate for the study. Data was analyzed using frequencies, means and multiple regression at p = 0.05. The results from the study showed that that reconstitution of the Newcastle vaccine and market access had statistically significant effects on the development of the indigenous poultry value chain in Vihiga District.

Khobondo (2018), conducted a study on the genetics and immunity of indigenous chicken in Kenya. The specific objectives of the study were: 1) to determine the sources of variation of Natural antibodies (Nabs) (IgG, IgM and IgA) binding keyhole limpet hemocyanin (KLH) amongst the IC, 2) to estimate the repeatability and variation of the ELISA assay (Nabs) with time within the IC, 3) to assess the diversity and population structure of IC using LEI0258 Marker, 4) to determine the effects of probiotic on IgM titre levels on IC 5) to determine composition and diversity of microbial populations in the chickens and 6) to identify potential bacterial species for use as probiotics for enhanced immunity. Blood was drawn from the wing vein of IC and plasma separated. Natural antibodies (IgM, IgA, IgG) titer values binding KLH were determined by indirect ELISA. One way ANOVA and Mixed model analyses were used to determine sources of Nab titer variation and estimate repeatability parameter. The results of the study showed that presence and variation of Nabs amongst the IC. The variance estimate for chicken components were high and significant for IgM (p=0.003), IgG (p=0.0001) and IgA (p=0.0001).The repeatability of the ELISA assay to Nabs was high in all the immunoglobulin isotypes. Repeatability was 0.68, 0.99 and 0.99 for IgM, IgG and IgA respectively.

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4.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

4.1 Introduction

This chapter summarizes the finding of the study, draws conclusions and makes recommendations necessary for formulation and the way forward.

4.2 Conclusion

The research found that Newcastle Disease outbreaks were experienced in the months of July to August and December to January. The mean annual temperature for the five years was in January was 21.8 0C while for December was 210C, July was 19.7 0C while in August 20.3 0C.Generally July recorded the lowest temperatures while February recorded the highest. There was a positive Pearson Correlation between temperature and ND in August, January and July. However, there was a negative correlation in December. The research concludes that there is a relationship between climate variables and ND.

Poultry farmers got many benefits from keeping of free range indigenous chicken. These included income, food (eggs and meat) and also source of self-employment. Among the challenges facing FRIC included; lack of enough feeds, predation and frequent outbreaks of diseases such as ND. ND occurred every year and its effects included: huge losses resulting from deaths, reduction in egg production, fluctuation of prices of chicken in the market and increase in production costs through purchase of drugs and vaccination.

From the study, it was found out that farmers use different methods to control the disease. These include use of traditional herbs such as grounded garlic mixed with water; grounded aloe mixed water, fresh milk and grounded mangoes.

4.3 Recommendations

On the basis of the findings of this study, the following are the recommendations that would improve the production in free range indigenous chicken, prediction and control of Newcastle disease.

Decentralize weather stations to location levels to enable monitoring of changes in temperature, rainfall and humidity so as to predict the occurrence of this disease and take early precautionary measures.

The government should employ more extension officers and decentralize veterinary offices to the sub-location levels so as to bring services to the farmer. This will enable farmers to get technical assistance without travelling long distances.

Establish quarantine system to curb the spread of the disease and also establish a slaughter house to allow inspection. This will ensure that only healthy chicken are sold to consumers.

Government to provide free drugs for vaccination and reduce the cost of feeds in order to reduce the cost of production for the poultry farmers

Farmers should keep poultry records especially on disease occurrence, season in which they occur, number of chicken that died and control measures. This will enable them to monitor the epidemiology of the disease and take early precautionary measures.

Government to educate small-scale farmers on how to adopt hygienic and bio-safe poultry rearing to minimize loss of chicken through diseases, pests and predation.This can be done through ensuring good housing system to protect chickens from strong winds and rains.

The government should facilitate improvement of productivity of indigenous chicken by commercializing the enterprise in order to improve food security and improve household incomes. This can be done through improving on the breeding management of indigenous chicken through purchase and distribution of improved breeding stock to farmers.

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