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Emmanuel Oduro Okata & Ramatu M. Al-Hassan

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Does publishing poultry vaccination schedule increase awareness and compliance among small-scale farmers? Evidence from Eastern Ghana

Emmanuel Oduro Okata[1]* and Ramatu M. Al-Hassan[1]

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*Corresponding author: Emmanuel Oduro Okata, Department of Agricultural Economics and Agribusiness, School of Agriculture, University of Ghana, Accra, Ghana
E-mail emmanuelokoduro@gmail.com

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Abstract: Poultry vaccination reduces birds' mortality risk and its related economic impacts. The Veterinary Services Directorate of Ghana publishes a national poultry vaccination schedule for farmers to comply with. Yet disease outbreaks occur, raising the question of whether poultry farmers comply with the vaccination protocols. This paper assesses vaccination compliance and its determinants among small-scale farmers, using Birim Central Municipality as a case study. We employed descriptive statistics, Kendall's coefficient of concordance and a Poisson count model to analyse cross-sectional data collected from 60 poultry farmers. We find that level of awareness about vaccination is higher than the level of compliance. The Poisson model reveals that access to veterinary services, poultry management training, large flock size, and having experienced poultry disease on the farm positively affect the extent of compliance with the schedule. On the other hand, male farmers are less likely to comply than female farmers. The most pressing constraints to poultry vaccination are inadequate access to finance, inadequate veterinarians and high cost of veterinary services. We recommend that poultry industry stakeholders take necessary measures to increase farmers' contacts with veterinary officers and intensify peer education on vaccination.

Subjects: Agriculture; Agricultural Economics; Agriculture and Food; Meat & Poultry

Keywords: small-scale; poultry; vaccination; compliance; awareness

1. Introduction

In Ghana, small-scale poultry production is a source of livelihood support for most rural farmers. It contributes to the Ghanaian economy in terms of employment creation, income source, organic manure for crop production, and source of food and nutrition. Poultry species commonly reared commercially in Ghana are chicken (broilers and layers), guinea fowl, turkey, ostriches, and ducks. It is estimated that small-scale poultry producers raise about 50 to 5000 birds; the sector also includes backyard production: these account for about 95% of the country's poultry population (USDA, 2013). Ghana has faced several viral diseases affecting poultry farms. The country's most important poultry viral diseases include Newcastle, Infectious Bursal disease (Gumboro), Avian Influenza, Infectious Bronchitis and

Marek's disease (Obeng, 2022). These are highly contagious viral diseases affecting birds of all ages, with young birds being the most vulnerable. Outbreaks of poultry diseases have had devastating effects on the poultry industry as well as other sectors of the economy.

Historically, the outbreak of highly pathogenic avian influenza (HPAI), commonly known as avian influenza (AI) as well as the speculation and fear of occurrence of the HPAI from 2005 to 2016, led to significant economic losses to many actors in the poultry value chain (FAO, 2014). Avian influenza vaccination is not currently practiced as a routine control measure in Ghana due to the potential for the virus to mutate and develop resistance to the vaccine.

The government of Ghana has implemented measures to prevent the introduction of avian influenza into the country, such as banning the importation of live birds and poultry products from countries where the disease is known to be present. Additionally, the government has established a national avian influenza surveillance programme to monitor and control the spread of the disease if it is detected. In the event of an outbreak, the government may consider vaccination as part of the control measures.

The frequent outbreaks of Newcastle and Infectious Bursal disease worsened the situation, affecting the demand for imported and locally produced poultry meat (Aning, 2006). Nonetheless, consumers' interest was restored after various poultry stakeholders organised awareness programmes about the importance of vaccinations. Given this, poultry farmers were advised to vaccinate their birds against contagious diseases by following a recommended vaccination schedule published annually by the Veterinary Services Directorate (VSD) of the Ministry of Food and Agriculture (MoFA). The generic vaccination protocols published by the Veterinary Services Directorate for poultry farmers across the country include Gumboro intermediate/Plus, Lasota, Newcastle disease vaccines and 1st & 2nd Fowl pox vaccines (Table 1). Vaccination protocols are normally developed based on scientific evidence and industry best practices. These protocols are reviewed and modified regularly to reflect changes in disease prevalence and new research discoveries. VSD may consult with other stakeholders such as veterinarians, animal health specialists, and industry groups. The VSD disseminates vaccination regimens through numerous means once they have been developed and approved. These may include publishing them on their website, disseminating them to veterinary service outfits and animal health specialists, and providing farmers and other stakeholders with training.

Table 1. National poultry vaccination schedule

Age		Vaccine
Week	Day	
1	7	Gumboro Intermediate
2	14	HB1[1]
3	21	Gumboro Intermediate Plus[2]
4	28	Lasota
5	35	Gumboro Intermediate/Plus[3]
8	53	1st Fowl Pox
10	70	Lasota
12	84	2nd Fowl Pox
16	112	3rd Newcastle Vaccine

Source: Veterinary Service Directorate press release in Daily Graphic (4 October 2018).[4]

Poultry vaccination regimes in Ghana have evolved over time, reflecting changes in the types of diseases affecting poultry and advancements in vaccine development and distribution. In the early years of Ghana's poultry industry, vaccination programmes primarily focused on controlling and preventing outbreaks of Newcastle disease, a major problem in the country. Vaccination against Newcastle disease was initially carried out using imported live vaccines. However, high cost of these vaccines made them inaccessible to many small-scale farmers. In the 1980s, the government of Ghana introduced a national vaccination programme for Newcastle disease, which included the development and distribution of affordable inactivated vaccines (Owusu-Ansah et al., 2016).

In the 1990s, a vaccination programme for Infectious Bursal Disease (IBD) was also introduced, as this disease had become a major problem in Ghana's poultry industry. IBD vaccine was also initially imported, but later, local production of the vaccine was established to increase accessibility and affordability for farmers (Adongo et al., 2020). Today, the National Poultry Vaccination Schedule developed by the Ministry of Food and Agriculture includes vaccination against Newcastle disease, IBD, and Fowl pox. The schedule recommends a regular vaccination regime for poultry flocks, which is essential for preventing and controlling these diseases.

Vaccination has proven to be one of the best safeguards against poultry viral diseases such as Infectious Bursal disease, Newcastle, Avian Influenza, and Fowl pox. Vaccination boosts immunity and protects birds from these diseases; it improves food production effectiveness and prevents transmission of zoonotic diseases to humans (Roth, 2011). In addition, vaccination reduces mortality risk, protecting farms from the total loss of birds. Domenech et al. (2009) opine that vaccination provides additional time for adaptations to be made to farming and marketing structures to reduce the long-run risk of infection, thus allowing poultry farmers to plan well financially.

Copland (2002) notes that rural small-scale and backyard farmers' overall awareness of poultry vaccination has declined despite the need for vaccinations. These farmers tend to use traditional herbs to control poultry diseases (FAO, 2009) without visiting the veterinary service outfits. Turkson (2008) reports that over 50% of poultry farmers in Peri-Urban Ghana administer vaccines themselves. These farmers may not have the expertise in vaccination and may therefore encumber the effectiveness of disease control in the poultry sector.

In addition, Annan-Prah et al. (2012) explain that most farmers in Ghana do not vaccinate their birds due to negative perceptions toward vaccination. The notable ones include negative perceptions about the effectiveness of vaccines, vaccination cost, accessibility to vaccines, and availability of vaccines or veterinary drugs (MOFA, 2004). Nkansah et al. (2020) and Asante et al. (2019) identified several factors that influenced the perception and attitude of small-scale poultry farmers towards vaccination in Ghana. These factors included the timing and frequency of vaccination, the quality of vaccines, the source of vaccines, and the knowledge and awareness of vaccination practices. These perceptions adversely impact the adoption of vaccinations and other related disease preventive measures.

Poultry farmers' non-adherence to routine treatment and vaccination schedules poses a serious threat to the poultry industry since diseases can escalate and have serious economic impacts. Delays in publishing vaccination schedules for poultry farmers and farmers' low willingness to comply with the recommended vaccinations have also been challenging in the poultry sector (FAO, 2014). Despite these reports, there is limited evidence about vaccination compliance among poultry farmers. To contribute to the existing knowledge, this paper assesses small-scale poultry farmers' compliance with the commercial poultry vaccination schedule in the Birim Central Municipality. Specifically, the study assesses factors influencing compliance with vaccination schedules. The study further identifies farmers' constraints in vaccinating poultry and offers policy recommendations to address the issues.

Figure 1. Conceptual framework for farmers' compliance with the commercial poultry vaccination schedule.

Adapted from Chilonda and Van Huylenbroeck (2001)

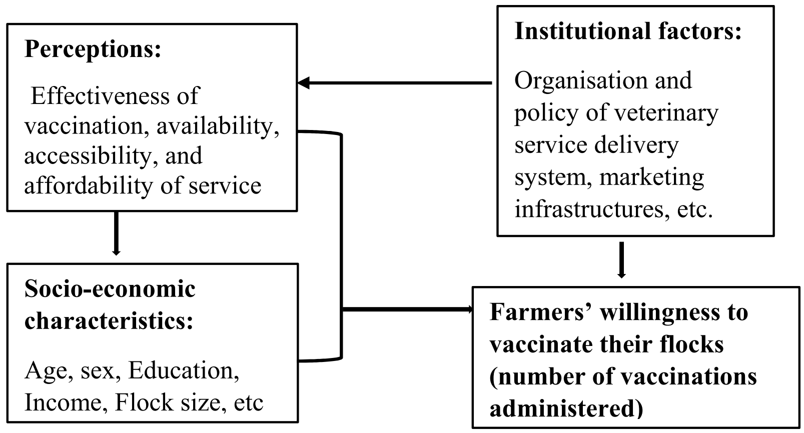
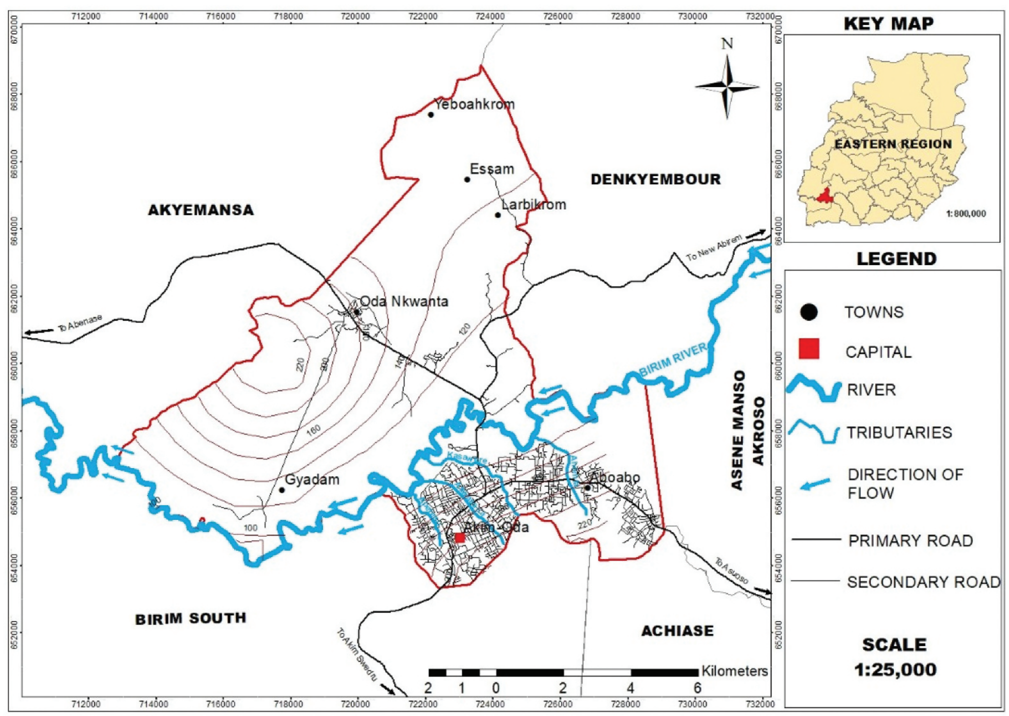


Figure 2. Map of birim central municipality.



2. Materials and methods

2.1. Conceptual framework

The conceptual framework in Figure 1, partly based on the available literature, explains the factors influencing small-scale farmers' decisions to vaccinate their flock. The framework indicates that small-scale farmers will comply with the vaccination schedule depending on perceptions about the vaccination, socioeconomic characteristics, awareness, attitude and knowledge of disease outbreaks. Institutional factors such as the organisation and policy of the veterinary services delivery system and marketing infrastructure may also influence farmers' decisions to comply with vaccination schedules.

Farmers' compliance level will depend on their socioeconomic characteristics, such as age, education, experience, and income (Nweze et al., 2019; Olowolaju et al., 2017). The level of education is an essential factor that can influence farmers' compliance with vaccination schedules because education enlightens farmers on how infectious diseases can be transmitted and the consequences of not adhering to disease prevention protocols. It is expected that farmers who have higher experience in poultry production and have frequent contact with veterinary or extension services would be aware and more likely to comply with the schedule. For instance, experienced farmers may have felt the impact of poultry diseases at least once on their farm and as a result, are more likely to comply to avoid future risks or impacts.

The institutional factors relate to general infrastructure, proximity to veterinary and/or extension services, information sources, and the policy and organisation of veterinary delivery systems (Chilonda & Van Huylenbroeck, 2001). Farmers are expected to comply with the vaccination schedule if the delivery of veterinary services is accessible (veterinary services are available and close to them). Furthermore, credit availability will help farmers overcome liquidity challenges, while veterinary personnel will encourage them to comply.

2.2. Estimation Methods

The econometric model used to explain the number of vaccinations a farmer complies with is based on an assertion by Gardner et al. (1995) that count data models are more credible than simple linear regression models such as OLS, logit, and probit regression models when the dependent variable is discrete and contains positive integers. A set of count data can be reduced to categorical data which can be analysed using either a logistic or probit regression model. However, its output distorts information and reduces statistical powers (Gardner et al., 1995). Mensah-Bonsu et al. (2017) describe count data models as more appropriate to explain adoption intensity when the dependent variable is discrete.

In this study, Poisson and negative binomial regression models explain the number of vaccinations a farmer complies with. Several researchers (Carrer et al., 2017; Castle et al., 2016; Isgin et al., 2008; Mensah-Bonsu et al., 2017; Pokhrel et al., 2018) have used either Poisson and/or negative binomial regression model to explain factors influencing technology adoptions. A Poisson regression model describes the relationship between the covariates (explanatory variables) and the count dependent variable (i.e. the number of vaccinations a farmer administers). The Poisson model is stated as follows:

$$Pr(Y_i = y_i/X_i) = \frac{e^{-\mu_i}\mu^y}{y!}, \text{where } y_i = 0, 1, 2, 3 \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where Y_i is the number of vaccinations administered by a poultry farmer *i*, and X_i is a vector of covariates. The mean parameter (μ) can be expressed as a function of the covariates (X_i) and the regression coefficient parameters (β_i):

$$\mu = E(y_i/X_i) = \exp(X'\beta) \quad (2)$$

$$exp(X'\beta) = exp(\beta_0) + exp(\beta_1 X_1) + exp(\beta_2 X_2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots + exp(\beta_k X_k) \quad (3)$$

Finally,

$$In(Y) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + \beta_k X_k + \varepsilon_k \quad (4)$$

The Poisson model also assumes that the mean is the same as the variance, i.e. no over-dispersion and the errors follow a Poisson distribution, not a normal distribution.

$$Var(y_i/X_i) = \mu(X_i, \beta_i) = exp(X'\beta) \quad (5)$$

Usually, in practice, the variance is not equal to the mean in which case, the assumption under the Poisson model is violated. When the variance is higher (lower) than the mean the model becomes over-dispersed (under-dispersed). If an under or over-dispersion problem occurs, the negative binomial model is more appropriate since the model includes random components that depict uncertainty about the true rate at which an individual event occurs (Gardner et al., 1995). The negative binomial model is expressed as:

$$Pr(Y = y_i/\mu, \alpha) = \frac{\Gamma(y + \alpha^{-1})}{\Gamma(y + 1)\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu}\right)^{\alpha^{-1}}\left(\frac{\mu}{\alpha^{-1} + \mu}\right)^{y}, \quad (6)$$

$$Var\left(\frac{y}{x_i}\right) = \mu + \alpha\mu^2 \quad (7)$$

Where Γ is the gamma parameter, α denotes the degree of dispersion, and over-dispersion exists when α is greater than 0. Based on equation 4, the empirical model to estimate is:

$$\begin{aligned} ln(NVAC_i) = {} & \beta_0 + \beta_1 GEN_i + \beta_2 AGE_i + \beta_3 EDU_i + \beta_4 FSIZE_i + \beta_5 EXP_i + \beta_6 PMGT_i + \beta_7 PDEXP_i \\ & + \beta_8 ACC_i + \beta_9 AVET_i + \beta_{10} INC_i + \varepsilon_i \end{aligned} \quad (8)$$

In this study, the decision to reject or accept either Poisson or negative binomial model is based on the significance of the α coefficient for the negative binomial model, Deviance goodness-of-fit for the Poisson model, Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC).

2.3. Variable description and sign expectation

The description, measurement and a prior expectation of the variables used in the empirical model are presented in Table 2. Definitions of the variables are presented as follows:

2.3.1. Number of vaccinations (NVAC)

This is the dependent variable and represents the number of vaccinations present in the schedule and administered by a farmer. In all, eight major different vaccination types in the national poultry vaccination schedule are presented in Table 1.

2.3.2. Gender (GEN; Male = 1)

This variable refers to the sex of the respondents and is measured as a dummy variable. The male and female farmers are assigned a value of 1 and 0, respectively. The coefficient of gender can either be positive or negative. For instance, male farmers are expected to positively influence vaccination decisions because males are often seen as the heads and custodians of family

Table 2. Description and measurement of variables and a-priori expectations

Variable	Description	Measurement	A-prior expectation
NVAC	Number of vaccinations administered	Count (0, 1, 2, ... 8)	
GEN	Sex of the respondent	1= male, 0 = female	±
AGE	Age of the respondents	Years	±
EDU	Respondents' educational level	1 = formal education, 0 = no education	+
PMGT	Training in poultry management	1 = Yes, 0 = No	+
EXP	Farmers experience in poultry farming	Years	+
FSIZE	Flock size	Birds	+
PDEXP	Farmers experience with poultry disease	1 = Yes, 0 = No	+
ACC	Access to credit	1 = Yes, 0 = No	+
AVET	Access to veterinary services	1 = Yes, 0 = No	+
INC	Monthly Income level	1 = above GHS500 0 = GHS500 and below	+

resources; hence, observing all the vaccination protocols may somehow depend on the farmer's gender. Agricultural technology adoption may depend more on a person's access to resources than on gender (Mwangi & Kariuki, 2015), and therefore, gender effects on adoption intensity may be ambiguous. However, other studies (Acheampong et al., 2016; Anaglo et al., 2017; Donkoh et al., 2019) have found that gender significantly affects the adoption intensity of agricultural technologies such as improved crop varieties and agronomic practices, but in different directions.

2.3.3. Age of the farmer (AGE; years)

This is a continuous variable measured in years and captures the age of poultry farmers. The sign of age coefficient is ambiguous because the effect of age on the number of vaccinations administered by a farmer is not certain and independent. A positive relation will exist if relatively young farmers are aware of the importance of poultry vaccination and are risk averse. Similarly, relatively aged farmers may comply with the vaccination protocol if they are also aware of the consequences of not vaccinating the birds. Therefore, the age effect is neither certain in the literature nor in this study.

2.3.4. Education (EDU; farmer has formal education = 1)

This variable indicates whether a poultry farmer has some level of formal education or not. This dummy variable equals zero (0) if a farmer has no formal education and one (1) if a farmer has attained some formal education such as primary education, secondary and tertiary education. Formal education is expected to positively affect the number of vaccinations a farmer will administer to the flock. It is assumed that formal education will increase farmers' awareness, access to information and ability to make rational decisions concerning disease prevention at the farm level.

2.3.5. Flock size (FSIZE; number of birds)

This variable captures the number of poultry birds owned by a farmer at the time of the survey. Flock size was recorded as a continuous variable and is expected to positively influence farmers' decisions to comply with the national vaccination schedule. Thus, the larger the flock size, the higher the number of vaccinations a farmer will administer to birds. In this study, the number ranges between 30 and 2000 birds of poultry.

2.3.6. Farmer experience (EXP; years)

this variable measures a farmer's years of experience in poultry production. A farmer's experience in poultry farming is expected to have a positive relationship with the number of vaccinations a farmer will administer. This expectation is because experience comes with its lessons, and it is assumed that farmers learn their lessons through experience.

2.3.7. Poultry management training (PMGT; has management training = 1)

This is a dummy variable that indicates whether a farmer has had any form of training in poultry management, especially with disease management. It is assumed that through this management training, farmers will appreciate the need to vaccinate birds. This variable is expected to have a positive relationship with the number of vaccinations administered.

2.3.8. Disease experience (PDEXP; experienced poultry disease = 1*)*

This is a dummy variable that indicates whether farmers have experienced at least one poultry disease on their farm, and it is assigned a value of one (1) otherwise zero (0). Farmers' experience with poultry disease is expected to positively influence the number of vaccines a farmer will comply with or administer to the birds. A farmer who has previously experienced disease outbreaks is more likely to vaccinate their birds fully.

2.3.9. Access to credit (ACC; farmer has access to credit = 1)

This variable refers to farmers' access to loans from financial institutions, government, or family and friends. This is a dummy variable with a value of one (1) if a farmer has access to credit and zero (0) if not. Access to credit is expected to positively influence farmers' decision to administer and comply with the national vaccination schedule because credit eases liquidity constraints to purchasing inputs, including vaccines.

2.3.10. Access to veterinary service (AVET; farmer has access to veterinary services = 1)
This variable captures a farmer's access to veterinary services such as farm visits and training. A farmer who has more contact with veterinary officers is expected to be more compliant and observe the vaccination protocol since the farmer may get first-hand information about poultry diseases from time to time. The variable is a dummy variable coded with 1, representing a farmer with access to veterinary service; otherwise zero (0).

2.3.11. Income (INC)
This is the estimated monthly earnings of the respondents measured in Ghana cedi (GHS). Income is dummied with 1 representing income level above GHS500.00 and 0 representing income below GHS500.00. This categorisation is based on our assumption that farmers who earn higher income (in this case, above GHS500.00 per month) are expected to have the capacity to purchase vaccines and other veterinary services, hence expected to follow the vaccination schedule.

2.4. Identifying and ranking the constraints to poultry vaccination
Seven (7) constraints to poultry vaccination were identified from the literature. They were pre-tested and presented to the respondents to rank them from the most pressing (assigned 1) to the least pressing (assigned 7). The constraints are (i) inadequate finance; (ii) high cost of veterinary service; (iii) inadequate veterinary officers; (iv) high cost of vaccines; (v) inadequate availability of vaccines; (vi) inadequate information on poultry diseases and (vii) farmer perception of vaccines as ineffectiveness (i.e., provide low immunity). The Kendall Coefficient of Concordance (W) was then used to test for agreement among the rankings of the constraints. The constraint with the smallest mean score is the most pressing constraint. The value of Kendall's coefficient, which ranges between zero and one indicates the degree of agreement. A value of 1 indicates a perfect agreement among farmers in the ranking of the constraints, and a value of 0 indicates perfect disagreement among respondents.

$$Kendall's\ Coefficient\ of\ Concordance(W) = \frac{[(12\left[\Sigma T)\right]^2 - \frac{\Sigma([T)]^2}{n}]}{m^2(n^3 - n)} \quad (9)$$

Where T = sum of ranks for challenges, m = number of respondents, n = number of challenges to be ranked by the farmers. To test for the statistical significance of Kendall's coefficient (W), chi-square static was used.

2.5. Sampling and data collection procedures
A two-stage sampling technique was used to select 60 small-scale poultry farmers in the Birim Central Municipality in the Eastern Region of Ghana. Four towns were purposively selected (Akim Oda, Oda Nkwanta, Akim Aboabo, and Akim Asene) based on a larger number of small-scale poultry production in these towns. Before selecting the towns, some staff of the Veterinary Service Directorate in the municipality were interviewed to understand how vaccinations are carried out in the study area. Information gathered included number of birds, vaccine types, vaccine prices, socioeconomic characteristics and how vaccines are administered in the study area. While information on bird types may be important for vaccination schedules, this study only focused on farmers' response to the vaccination schedule irrespective of the type of birds raised. In the second stage, a list of registered poultry farmers in the selected towns were obtained from the Municipal Department of Agriculture, but not all farmers were captured in the list. We randomly selected 60 poultry farmers with the assistance of extension officers to locate the farms. Fifteen (15) respondents were selected from each town because of financial constraints and challenges getting farmers to interview. Poultry farmers in these selected communities have other major farming activities which keep them occupied. The poultry farms are usually managed by caretakers hired by the farm owners. Since most of the farm caretakers were not in the capacity to share poultry-

specific information without the consent of the farm owners, we interviewed the farm owners only. Primary data was obtained using a structured questionnaire. The questionnaire asked about farmers' socioeconomic characteristics, level of awareness about the poultry vaccination schedule, level of compliance with the schedule, factors influencing compliance and constraints to farmers' compliance with the schedule. The main limitation of the data collection was the small sample size due to financial constraints and limited time to complete this study.

2.6. The study area

The study was conducted in the Birim Central Municipality of the Eastern Region of Ghana. The Birim Central Municipality shares a boundary with Akyemansa District to the north, Birim South District to the west, and Asene-Manso to the east. Akim Oda remains the capital town of the municipality. The land is primarily undulating and hilly with substantial rainfall since the municipal falls within the wet semi-equatorial climatic zone and semi-deciduous rainforest vegetation zone. The monthly mean temperature experienced in the municipality is around 26°C and ranges between 21°C and 35°C.

The municipality has a total population of 144,869, representing about 6% of the Eastern Region's total population (Ghana Statistical Service, 2014). About 55.9% of the households are into crop farming and livestock rearing. Poultry, sheep, goat, pig, and cattle are the main types of animals reared, constituting about 34.7 % of the municipality's agriculture activities. The dominant livestock is poultry such as chicken, duck, guinea fowl, and turkey. Aside from those who rear animals for commercial purposes, almost every household rear some kinds of animals as supplementary activities to complement their meat source and earn additional income. Small-scale livestock production is the dominant scale of operation in the municipality. Figure 2 illustrates the map of the study area.

3. Results and discussion

Table 3 presents summary statistics of the socioeconomic characteristics of the respondents. Seventy (70) percent of the respondents were male with an average age of 49 years. Most of the respondents (80%) were married. About 92% of the respondents had formal education (i.e., primary, secondary or tertiary education) with an average of 9 years of experience in poultry farming. The respondents also had an average flock size of 578 birds with few farmers (18%) having access to credit. The majority (88%) of the respondents had experienced poultry diseases, 60% reported having access to veterinary services and about 67% have had at least training in poultry management. About 47% of the respondents earn above GHS500 monthly. Also, 78% of the farmers were aware of the published national vaccination schedule. This finding is consistent with Yakubu and Abdul-Rahman (2018) who found most of the farmers (78%) had heard of poultry vaccination in Northern Ghana. The respondents who were aware of the schedule got to know through newspapers, extension/veterinary officers, and family/friends. It is important to note that approximately 71% of them had this information from the veterinary service directorate in the municipality. This makes the veterinary service directorate a principal source of information on disease prevention and control for poultry farmers in the Birim Central Municipality.

3.1. Compliance with poultry vaccination schedule

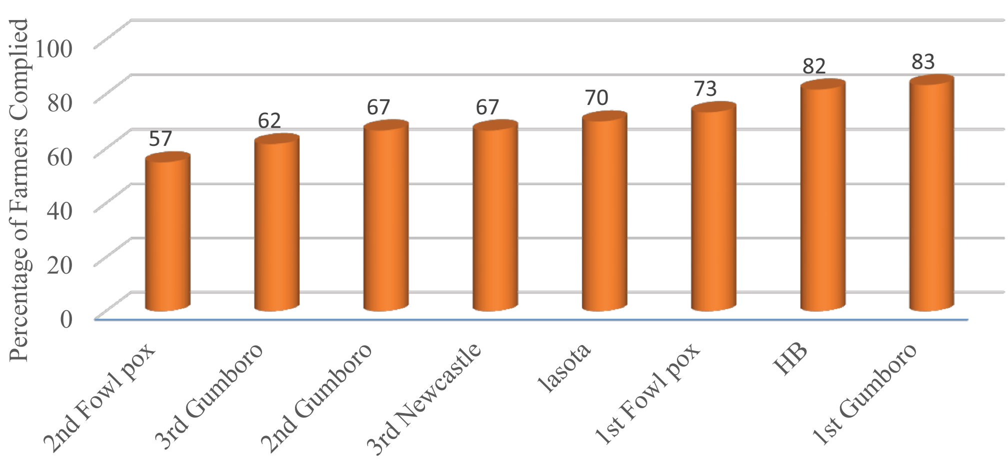
Figure 3 presents the distribution of farmers by the types of vaccinations in the schedule administered. The initial vaccinations for each specific disease recorded the highest frequencies. 1st Gumboro vaccination recorded the highest frequency of farmers among all the vaccinations, followed by HB and 1st Fowl Pox. We can also observe that the first vaccinations for Gumboro, Newcastle and Fowl Pox disease were administered more than the 2nd and 3rd vaccines. For instance, HB was the most administered vaccine for Newcastle diseases. This level of compliance is lower than the level of awareness of the national vaccination schedule presented in Table 3.

Table 4 presents the frequency distribution of farmers by the number of vaccinations they administer to their birds. Eighty-three percent (excluding the zero counts) of the respondents

Table 3. The socioeconomic characteristics of respondents

Categorical Variable		**Percentage (*n* = 60)**	
Gender	Male	70	
	Female	30	
Marital status	Married	80	
	Single	20	
Education	No education	8.3	
	Primary	25.0	
	High school	43.3	
	Tertiary	23.3	
Income	Less than GHS200	15.0	
	GHS200 - GHS500	38.3	
	Above GHS500	46.7	
Poultry Management Training	Yes No	66.7 33.3	
Poultry Disease Experience	Yes No	88 12	
Access to veterinary service	Yes No	60 40	
Awareness	Yes No	78 22	
Access to credit	Yes No	18.3 81.7	
Continuous Variable	**Mean**	**Min.**	**Max.**
Age	48.72	26	75
Farm experience	9.3	1	28
Flock size	577.72	30	2000

Figure 3. Distribution of farmers by individual vaccinations they complied with.



had administered at least one of the vaccinations in the schedule. It is alarming that 17% of poultry farmers have never administered any vaccinations in the schedule. This is detrimental to reducing disease outbreaks in the poultry industry. However, on average, farmers have vaccinated approximately 6 of the vaccinations, and only 55% of them had fully complied with the vaccination schedule. Though this percentage is quite encouraging, farmers did not administer all the vaccines as presented in the schedule. A study by Ayim-Akonor et al. (2020) showed that farmers do not comply with all the biosecurity practices recommended for farms, exposing the farms to the risk of

Table 4. Distribution of respondents by number of vaccinations administered	
Number of vaccinations (count)	**Percentage (*n* = 60)**
0	17
1	2
2	3
3	5
4	5
5	5
6	7
7	2
8	55
Total	100

disease outbreaks. The fact that 83% of respondents had administered at least one of the vaccinations in the schedule indicates that many farmers recognize the importance of vaccination in preventing disease outbreaks in their flocks. However, the finding that 17% of farmers have never administered any vaccinations in the schedule is alarming, as this increases the risk of disease outbreaks and can have negative impacts on animal welfare and economic gains.

The interviews revealed that financial constraints contributed to non-compliance; other factors were delayed arrival of the vaccines and emergencies that kept the farmers away from the farm site for some days. Some farmers opined that the services of veterinary officers are expensive. As a result, only a few hired veterinary officers to administer the vaccines to the birds. Due to this, most farmers rely on their personal experience to administer the vaccines themselves without seeking expert advice. The veterinary officer at the Birim Central Municipality explained that farmers feel reluctant to continue with the subsequent vaccinations after administering the first vaccine. He said, “farmers” level of education in this district is quite low, and therefore, they do not value the importance of vaccination.”Overall, the results suggest that efforts to improve compliance with vaccination schedules in the poultry industry should focus on addressing financial barriers, improving access to veterinary services, and providing education and training to farmers on the importance of vaccination in disease prevention. These efforts may help to reduce the risk of disease outbreaks and improve the overall health and welfare of poultry flocks.

3.2. Factors influencing small-scale poultry farmers’ compliance with commercial poultry vaccination schedule

Multicollinearity among the explanatory variables was tested to ascertain the suitability of the variables for the count model. Multicollinearity test results (see Appendix A) show low or no sign of multicollinearity among the independent variables. The Variance Inflation Factor (VIF) values were all less than 10, with a mean VIF of 1.96. This suggests that our covariates are suitable for the model and hence the regression coefficients are not poorly estimated.

Table 5 presents the estimated results of the Poisson regression. First, we estimated the negative binomial model and compared the results to the Poisson model. The variable coefficients of the two models showed no significant difference hence we relied on other goodness-of-fit statistics to determine the suitable model for the data. The likelihood ratio of the chi-square value is statistically significant at the 1% level, explaining that at least one of the regression coefficients is not equal to zero. However, comparing the Pseudo R^2 values, the Poisson model proves to be a better model for explaining the number of vaccinations administered by farmers. The alpha coefficient (which measures the degree of dispersion) for the negative binomial is statistically insignificant, meaning there is no over-dispersion. In addition, the value of Deviance goodness-of-fit (89.97; prob>$chi^2 = 0.0005$) for the Poisson model is statistically significant at 1%,

Table 5. Estimated results of poisson regression

Variables	Coefficients	Std. Errors	P-Values
Gender	−0.254*	0.134	.057
Age	−0.006	0.009	.498
Education	0.491	0.379	.195
Flock size	0.0003**	0.0002	.043
Farm experience	−0.010	0.016	.523
Poultry management training	0.328**	0.156	.035
Disease experience	0.417*	0.249	.094
Access to credit	0.144	0.144	.318
Access to veterinary service	0.569***	0.162	.000
Income	−0.005	0132	.971
Constant	0.583	0.499	.243

Observation = 60, LR chi^2 = 70.40, Prob > chi^2 = 0.000, Pseudo R^2 = 0.2039, AIC = 296.8058, BIC = 319.8436. *, ** and *** represent 10%, 5% and 1% significance levels, respectively.

suggesting an absence of over-dispersion or an excessive number of zeros in the data. Compared to the Poisson regression, the negative binomial regression has a larger AIC (Akaike's Information Criterion) and BIC (Bayesian Information Criterion) values. Therefore, the negative binomial model is rejected, and we present the results of the Poisson model for further discussion.

The Poisson regression results (Table 5) show that access to veterinary services, farmers who have had poultry management training, flock size, and those who have experienced diseases on their farms positively affect the number of vaccinations administered. Access to veterinary services is statistically significant at a 1% significance level and positively related to the number of vaccinations farmers administer. Farmers who have access to veterinary services may be well informed about the disease outbreak and the consequences of not putting measures to prevent them. They may be informed about the disease prevention management practices such as vaccinations and other biosecurity measures. Therefore, those farmers will be more likely to comply with such measures as Garforth (2015) has explained. That said, the number of vaccinations administered to birds will be expected to be higher when farmers have frequent access to veterinary services. Therefore, the Veterinary Service Directorate needs to increase poultry farmers' contact with veterinary officers.

Poultry management training is statistically significant at 5% and positively affects the number of vaccinations administered. This result implies that farmers who have training in poultry management, specifically disease management, are more likely to administer a higher number of vaccines than farmers without any poultry management training. This finding is consistent with a study by Darkwah et al. (2019). They found formal training positively associated with the number of soil and water conservation practices adopted by farmers. Musaba (2010) also found training in basic animal health as a significant factor influencing the adoption rate of livestock technologies. Training enlightens farmers on the best way to reduce risks, use resources efficiently and optimise profit. Since vaccination is a measure to reduce the risk of disease outbreaks, the number of vaccinations farmers will administer to their flocks will be affected by the kind of training they receive. The various institutions and stakeholders should organise regular sensitisation and training programs relating to poultry disease control and prevention to increase vaccination compliance in the poultry sector.

The coefficient of flock size is statistically significant at 5% and positively associated with the number of vaccinations administered. This result is consistent with a study conducted by Suwunnamek and Suwanmaneepong (2011), who found the number of pigs on the farm to be a significant factor in explaining farmers' compliance with environmental regulations. Darkwah et al. (2019) explain that farmers with larger farm sizes have the financial resources to improve technology adoptions. One would expect that farmers with larger flock sizes would be financially capable and more concerned about the impact of disease outbreaks and therefore would vaccinate birds more regularly than farmers with small flock sizes. This result implies that vaccination information should not only target farmers with large flock sizes but should cover all farmers irrespective of the farm size or the scale of operation in order to minimise national poultry mortality risk.

Farmers' experience with poultry diseases is statistically significant at 10% and is positively related to the number of vaccinations administered by poultry farmers. The result is consistent with a study carried out by Liverpool-Tasie et al. (2019), who found poultry farmers' experience with extreme heat to be positively associated with adoption of climate change adaptation strategies in Nigeria. Mensah-Bonsu et al. (2017) also found that farmers who experience severe food shortages are more likely to adopt land and water management practices in Ghana. It could be that farmers who have more years of experience in poultry farming may have experienced shocks of disease outbreaks and as a result, will be more willing to adopt disease prevention methods like vaccinations to reduce the impact of disease outbreaks. Hence, farmer-to-farmer contacts should be encouraged through field days where farmers who have experienced disease share the impact of their experience and how they have benefitted from vaccination with other farmers. By so doing, other farmers will be sensitised and comply with poultry vaccinations.

The coefficient of the gender variable is negative, indicating that male farmers tend to administer fewer vaccines than female farmers. In this study, male poultry farmers will tend to administer fewer vaccines than female poultry farmers as the parameter estimate of the gender variable indicates. This result is indirectly consistent with a study conducted by Acheampong et al. (2016), who found males more likely not to adopt improved agronomic practices. Poultry vaccination requires much attention as it takes effort to prepare birds for vaccination. It is believed that men relatively engage in more activities than women. Therefore, men will be less likely to be available on the farm to prepare birds for vaccinations or supervise vaccinations regularly. Acheampong et al. (2016) state that men find it more challenging to allocate time for farm activities than women since men spend more time on non-agricultural activities. This assertion reaffirms the estimated coefficient of the gender variable in this study; those female poultry farmers administer a higher number of vaccinations than male farmers. So, male farmers should be targeted with education on poultry vaccination while encouraging female farmers to continue to comply with the vaccination schedule.

3.3. Ranking of farmers' constraints to poultry vaccinations

Table 6 presents the constraints identified by the farmers and their respective ranks. Kendall's coefficient value of 0.722 is highly significant with a p-value of 0.000. This Kendall's coefficient value indicates 72% agreement among farmers with the ranking of the constraints. It shows a strong agreement level since it is closer to 1 than to zero (0).

Inadequate finance is the most pressing constraint facing small-scale poultry farmers in the study area. This is consistent with Anang et al. (2013), who identified inadequate finance as the major challenge in layer and broiler production in the Brong Ahafo region. The limited access to credit and loans constraints small-scale farmers in many ways. First, they are limited by the number of inputs used for production. Second, small-scale farmers' response to technology adoption is also constrained by inadequate financial support systems. The cost of vaccination becomes relatively higher for farmers without financial support such as credit and loans. The data reveals that most (82%) of the farmers have no access to financial support, which is critical and

Table 6. Constraints and their respective rankings

Constraints	Mean Rank	Position
Inadequate finance	1.20	1st
Inadequate veterinarians	3.12	2nd
High cost of veterinary service	3.20	3rd
High cost of vaccines	3.32	4th
Inadequate availability of vaccines	4.95	5th
Inadequate information on diseases	5.52	6th
Ineffectiveness of vaccines	6.70	7th

Kendall's coefficient = 0.722, Chi-Square = 259.971, Asymptotic significance =0.000.

detrimental to adherence to all vaccination protocols. This makes the cost of veterinary services and vaccines a major problem facing poultry farmers in the study area. Moving forward, financial support systems by the government such as Microfinance and Small Loans Centre (MASLOC), should be made more accessible to small-scale poultry farmers.

Inadequate number of veterinary officers is ranked as the second most pressing constraint. This constraint is due to a lack of animal health expertise in the study area. As of the time of the survey, the Birim Central Veterinary Service Directorate has only two qualified veterinary officers who serve all the farmers in the municipality. Due to this, farmers complain about the inability of the veterinary officers to meet their demands on time which leaves farmers with no option but to depend on their personal experience and administer vaccines. Depending on personal experience may lead to improper application of the vaccines resulting in vaccination failure. About 67% of the farmers indicated that they administer their vaccines. This result is not surprising because Boamah et al. (2016) found that about 98% of antibiotics administered to poultry birds in some selected farms in the Ashanti Region were done by non-veterinary officers. However, disease information and the effectiveness of the vaccines are not a major problem to the farmers since information on poultry diseases could easily be accessed from the office of the veterinary service directorate. Farmers who vaccinated also attested to the effectiveness of vaccination against poultry diseases. To sum up, these constraints can affect the extent of compliance by poultry farmers with the vaccination schedule and increase the risk of diseases and their related economic impacts.

4. Conclusion and recommendations

This paper concludes that publishing vaccination schedules through veterinary service outfits increase poultry vaccination awareness and compliance among small scale farmers. The study highlights access to veterinary services, poultry management training, flock size, gender and experience with poultry diseases as factors influencing vaccination compliance among poultry farmers in the study area. These factors should therefore be at the centre of policies to address non-compliance with vaccination in the country. Our study show that the awareness of vaccination schedule is higher than the compliance level among the respondents. Farmers do not administer all the vaccines in the national poultry vaccination schedule. This non-compliance among small-scale poultry farmers poses a severe threat and drawbacks to mortality risk reduction in the poultry industry. The reason can be attributed to the limited number of animal health personnel in rural areas and the high cost of veterinary services as well as lack of financial support systems. We recommend that the veterinary service directorate of MoFA should periodically organise or support sensitisation and awareness programmes on the need to vaccinate flocks to increase poultry farmers' compliance with vaccination schedules to reduce high mortality in the poultry sector. Government should support farmers in rural communities with some form of financial support for vaccination-related activities. Loans and other credit facilities must be accessible to poultry farmers with a flexible payment plan to help farmers expand the production scale and have the financial capability to adopt new agriculture technologies. Besides, there is also a need to increase the number of veterinarians and motivate them to visit and educate farmers on new poultry management practices regularly. The Veterinary Service Directorate of the Ministry of Food and Agriculture should take measures to increase poultry farmers' contact with veterinary officers for proper education and measures to reduce the incidence of rampant disease outbreaks. This paper highlights the importance of ensuring compliance with vaccination schedules to mitigate the economic and health implications of disease outbreaks in the poultry industry, not only in the study area but also in other areas with similar farming practices.

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Author details
Emmanuel Oduro Okata[1]
E-mail: emmanuelokoduro@gmail.com
Ramatu M. Al-Hassan[1]
[1] Department of Agricultural Economics and Agribusiness, School of Agriculture, University of Ghana, Accra, Ghana.

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Notes
1. HB1 most likely refers to a strain of the herpesvirus of turkeys (HVT) that is commonly used in combination vaccines to protect against Marek's disease (MD) in poultry.
2. Referred to as 2nd Gumboro vaccine in this study.
3. Also referred to as 3rd Gumboro vaccine.
4. This chart was confirmed by the municipal veterinary officer at the Birim Central Veterinary Service Directorate.

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Appendix A: Multicollinearity Test

Variables	**Variance Inflation Factor (VIF)**
ACC	1.12
GEN	1.17
PDEXP	1.23
DINC	1.41
DEDU	1.52
PMGT	1.55
AVET	1.78
FSIZE	2.26
EXP	3.40
AGE	4.12
Mean VIF	**1.96**