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RESEARCH ARTICLE

POULTRY FARMERS' KNOWLEDGE AND PREVALENCE OF SALMONELLA INFECTION IN RELATION TO HANDLING AND BIOSECURITY MEASURES IN OYO STATE, NIGERIA

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Abstract

Poultry-related illnesses, such as Salmonellosis, continue to pose a significant threat to poultry farming in Oyo State, Nigeria. The expenses associated with treating and controlling these diseases tend to raise overall production costs, which in turn reduces the profit margins for poultry farmers. Against this background, this research was designed to identify the understanding and incidence of Salmonella infection among poultry farmers in Oyo State, Nigeria, as it relates to handling and biosecurity control. Primary data were collected from 120 poultry farmers using a cross-sectional survey conducted through a multi-stage sampling method and a structured questionnaire. The data were analysed using descriptive statistics and multinomial logit regression. Most of the respondents (77.5%) were aged between 26 and 55 years, with 70.8% being male, 50.8% married, and 85.0% having received formal education. The average years of poultry farming was 15±7.57 years, and 59.2 % of the sample was Yoruba. The findings also demonstrated that all the poultry farmers were aware of Salmonella, and over 78.6% knew the source of Salmonella through seminars, extension workers, family/friends, and the Agricultural Development Programme (ADP) in Oyo State. The study revealed that disease prevention is very relevant in managing poultry diseases, comparable to the impact of medication and insurance. Notably, 62.5 % of the poultry farmers were found to engage in low-level disease management practices. It was also demonstrated that key factors influencing the effectiveness of poultry disease control in the area included gender, educational attainment, household size, farming experience, marital status, nationality, ethnicity, and the scale of poultry operations. Based on these findings, the study recommends strengthening extension services and the roles of Agricultural Development Programme (ADP) officers. Additionally, it calls on the government to develop policies that enhance poultry disease management practices.

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Introduction: -

The agricultural sector is the primary contributor to Nigeria's economy, accounting for over 38% of the nation's non-oil revenues. It also employs nearly 70% of the active working-age population. Furthermore, it has been proven that the poultry sub-sector is the most commercialized of all agricultural sub-sectors in Nigeria (Adene and Oguntade, 2008) and has reshaped the lives of less privileged individuals in society through minimal investment and low technology costs. Its average production is 454 billion tonnes of meat and 3.8 million eggs each year, and the population primarily consists of approximately 180 million birds (FAO, 2018).

Animal protein sources in Nigeria, like in most developing economies, are primarily dominated by poultry meat and eggs due to their affordability and acceptability (Bettridge et al., 2014; Fagbamila et al., 2017). Regrettably, a series of infectious diseases, such as salmonellosis, threatened the sustainable growth of this significant sub-sector. Thus, to the best of our knowledge, there are few published studies on circulating strains of Salmonella in poultry production in Nigeria (Rauf et al., 2014; Fagbamila et al., 2017), and the risk factors associated with different types of *Salmonella spp*. It has barely been studied.

The populace depends on this industry as the source of nutritional benefits such as animal protein, vitamins, minerals, and fats and oils, raw materials to produce organic fertilizers and animal feeds, among others, may be because of low or no distinction against poultry and poultry products and availability and low cost (Fagbamila et al., 2010; Bettridge et al., 2014). Therefore, the poultry industry has remained crucial to Nigeria's economic development. Poultry-associated salmonellosis is a widespread global issue, resulting in morbidity, mortality, and financial losses (Akter et al., 2007; Kwon et al., 2010; Abiodun et al., 2014; Ahmed et al., 2017).

Salmonella, like most *Enterobacteriaceae*, are motile by peritrichous flagella except *Salmonella pullorum* and *Salmonella gallinarum*, which lack flagella (Bhunia, 2008). Salmonella is categorized into two primary species: *Salmonella enterica* and *Salmonella bongori*. Most pathogenic species of Salmonella that affect people encompass the *S. enterica*. Over 2,500 serotypes have been reported due to differences in the somatic (O) and flagella (H) antigens (Solari et al., 2003; Barde et al., 2017). However, a recent report from the Centre for Infectious Disease Research and Policy classifies members of the Salmonella species into more than 2541 serotypes (serovars) according to their somatic (O) and flagellar (H) antigens (CIDRAP, 2006).

The pathogen primarily resides in the intestinal tracts of animals, birds, mice, and farm animals, and occasionally in eggs (Ellermeier and Slauch, 2006). The Salmonella-caused disease is significant because it can be transmitted to offspring periodically. The control of salmonellosis in the poultry industry is complex because, in addition to vertical transmission from parent stock to offspring, horizontal transmission on farms is also prevalent, making its control a challenge (Dawoud et al., 2011; Hannah et al., 2011; Abiodun et al., 2014). This is possible through infected litter, water, dust, fluff, insects, faeces, feed, equipment, fomites, and diseased chicks and rodents, all of which can be contaminated with Salmonella (Poppe 2000). Other animals, wild birds, and personnel may also transmit them.

However, it has been reported that poultry farms and poultry products are the primary sources of Salmonella contamination (Hussein et al., 2009). Studies on numerous poultry diseases occurring in specific regions of the country have shown that salmonellosis is the primary threat to poultry production (Mamman et al., 2014). Additionally, animal droppings have been identified as a potential reservoir for many enteric organisms (Raufu et al.,2013). Hence, consumers of poultry and poultry products are at risk of contracting salmonellosis through the consumption of contaminated products (Adesiyun et al., 2005; Mughini-Gras et al., 2014). Salmonella Infection in poultry farms is a common problem of great interest to both the health of the population and the socio-economic well-being of the country it affects, due to the destruction it can inflict.

Furthermore, it has been estimated that the total costs for medical care and lost productivity resulting from foodborne Salmonella infections in humans were between $0.6 and $3.5 billion annually (CDC, 2009; Majowicz et al., 2010). The other costs associated with Salmonella include factors ranging from direct expenses incurred by producers due to Salmonella infections in chicken stocks. Preventive measures, such as biosecurity procedures, facility cleaning and disinfection, rodent management programs, vaccination, and testing, can all significantly add to the cost of production.

Moreover, Salmonella contamination of food products can significantly reduce consumer demand and affect producer profits (Namata et al., 2008). One of the largest and most significant sources of paratyphoid (PT) Salmonella in the human food supply is through the commercial poultry industry. Controlling paratyphoid (PT) infections has thus become an essential objective for the poultry industry from both public health and economic perspectives (Gast, 2003). In addition, food safety has been studied with everyone's concern regarding production, transportation, processing, food storage, and food preparation.

Nevertheless, despite the amount of knowledge we have, there is still more to unravel about food safety and the complete control of salmonellosis within the poultry industry, with greater structural focus on Oyo State, Nigeria, within the whole farm-to-fork production model. Moreover, Oyo State has also been referred to as an example of a civil servant state due to the large number of civil servants and the existence of thousands of unemployed graduates who find ways to supplement their income. This singular factor has triggered the boom in poultry keeping in Oyo State.

The poultry industry in Oyo State, Nigeria, is substantially hindered by salmonellosis in its pursuit of a private sector-driven economy and microeconomic stability. In contrast, the disease outbreak in the poultry industry is not given sufficient consideration in the team's foresight and preventive measures. Therefore, to prevent Salmonella contamination of broiler/layers, one must be aware of the most critical risk factors involved in the existence of Salmonella within the poultry production system. Thus, we aim to investigate the knowledge and prevalence of Salmonella infection among poultry farmers in Oyo State, Nigeria, in relation to their handling practices and biosecurity control measures.

Materials and Methods: -

Study area

The research was conducted in Oyo State, Nigeria, situated between latitudes 7°03′ and 9°12′ North of the equator and approximately 2°47′ East of the prime meridian. The region experiences two main climatic seasons. The state is made up of 33 local government areas in four agricultural zones (Ogbomosho zone, Ibadan/Ibarapa zone, Oyo zone, and Oke Ogun zone) and three senatorial districts (Oyo North, Oyo Central, and Oyo South senatorial districts) with a population of 5,591,585 people (National Population Commission, 2006).

Oyo State shares its northern border with Kwara State, its southern border with Ogun State, its eastern border with Kwara and Osun States, and its western border with the Republic of Benin. The region’s favourable climate has encouraged about 70 % of residents to engage in agriculture, cultivating both permanent and food crops. Small-scale farmers comprise most of the farming population in the state.

The population is predominantly Yoruba, speaking the Yoruba language, with a rich cultural heritage and strong kinship ties that unify the community.

Climatically, Oyo State experiences a moist equatorial climate characterised by hot, dry, and wet seasons with moderate humidity. The dry season lasts from November to January, while the wet season spans from April to October.

Temperatures typically range between 25 °C (77 °F) and 35 °C (95 °F) throughout the year. These favourable weather conditions have contributed to the popularity of poultry farming among local farmers (Adeyonu, 2015). Vegetation-wise, the southern part of Oyo State is covered by rainforest, while the northern part features guinea savannah. Dense forests dominate the south, whereas the north consists mainly of grasslands interspersed with trees.

Figure 1: Map showing the thirty-three Local Governments in Oyo State.

Poultry and poultry farm handler sampling: -

The study, conducted over 5 months (July 2021 - November 2021), spanned 18 commercial poultry farms. All the farms were sampled twice, and 10 respondents were sampled on each farm, with different respondents per farm comprising attendants, supervisors, security personnel, managers, and others.

The participants were requested to read the questionnaire attentively, considering the study topic upon due introduction. A total of one hundred and twenty (120) questionnaires were received at the end of the study and analyzed accordingly, as they were found to provide valuable data for the study.

Farm description: -

Poultry production systems can be categorized into five intermediate categories based on the four operational classes defined by the Food and Agriculture Organization (FAO), which are determined by the number of chickens raised on a farm (FAO, 2018). The poultry farms were classified based on size as backyard farms (under 200 birds), semi-commercial farms (200 to 999 birds), small-scale farms (1,000 to 4,999 birds), medium-scale farms (5,000 to 9,999 birds), and large-scale farms (over 10,000 birds).

Most of the farms included in this study fell into the medium-scale or large-scale categories. Although grandparent breeds are mainly imported to Europe, well-established breeding farms exist in the Oyo State study area in Nigeria. Day-old chicks are primarily produced in the region sampled by both large and small hatcheries and transported by road to various parts of Nigeria (Adene and Oguntade, 2008).

Administration of a structured questionnaire

Study participants and poultry owners were given a structured questionnaire that included the required information, along with a request for voluntary and informed consent. The level of poultry disease management was derived from the poultry disease management index, as earlier categorized by Lestari et al. (2011) as (1) Low level (0 up to 0.33), (2) Moderate level (0.34-0.66), and (3) High level (0.67-1.0). The three dimensions (Biosecurity practices, Medications, and Insurance) and attributes, as shown in Table 6, were selected using the approach outlined by Britz (2011).

Multinomial logit model

The factors influencing the level of poultry disease management among egg farmers in Oyo State, Nigeria, were analyzed using a multinomial logistic regression model. The dependent variable was the level of poultry disease management, categorized as low, moderate, or high. To estimate the model, one category had to be designated as the reference group, which in this case was the least desirable option (i.e., low). The model predicts the probabilities of each management level based on the individual characteristics of the poultry egg farmers (Maddala, 1983).

With three possible choices (s = 1, 2, 3), the multinomial logit model calculates the probability P_{is} that the i- The poultry egg farmer falls into the category s. Vector z represents the farmers' characteristics. The likelihood of selecting a particular option is determined by the utility of that choice being greater than or equal to the utility of the other alternatives. Following Babcock et al. (1995), the multinomial logit model for the three poultry farm categories (s = 1, 2, 3) can be defined as:

$$P(Y = s) = \frac{e^{\delta jz}}{1 + \sum_{j-2}^{s} e^{\delta jz}} \text{ for s not equal to 1} \quad (1)$$

$$P(Y = 1) = \frac{e^{\delta jz}}{1 + \sum_{j-2}^{s} e^{\delta jz}} \quad (2)$$

X_1 to X_{13} represent the independent variables in this study that influenced the level of poultry disease management among poultry egg farmers in Oyo State, Nigeria. The explanatory variables included in the model are similar to those used in previous related studies, as outlined earlier by Ojo (2003), Oladeebo and Ambe-Lamidi (2007), Adepoju (2008), Olagunju and Babatunde (2011), Isiorhovoja (2013), and Akintunde and Adeoti (2014).

Statistical analysis: -

Epi Info (version 7.0) was used for data management, Microsoft® Office Excel 2010 Professional Edition for data entry, and SPSS (version 21.0) for data analysis. The data were analyzed through descriptive statistics, fuzzy set analysis, and multinomial logit regression.

Result: -

Socio-demographic characteristics of poultry farmers

Table 1: Socio-economic characteristics of the respondents (n = 120).

Variables	Frequency	Percentages (%)
Age		
15-25	16	13.3
26-35	39	32.5
36-45	33	27.5
46-55	21	17.5
Above 55	11	9.2
Sex		
Male	85	70.8
Female	35	29.2
Marital Status		
Single	43	35.8

Married	61	50.8
Divorced	8	6.7
Widowed	3	2.5
Separated	5	4.2
Educational qualification		
No formal education	18	15.0
Primary education	22	18.3
Secondary education	50	41.7
Tertiary education	30	25.0
Religion		
Islam	71	59.2
Christianity	47	39.2
Traditional	2	1.7
Tribe		
Yoruba	71	59.2
Igbo	30	25.0
Hausa/Fulani	13	10.8
Igede	6	5.0
Nationality		
Nigerian	93	77.5
Foreigners	27	22.5
Years of poultry farming experience		
1 – 9	53	44.2
10 – 17	47	39.2
18 – 25	14	11.7
26 – 33	6	5.0
Number of staff/workers		
1 – 5	38	31.7
6 – 10	24	20.0
11 – 15	20	16.7
16 – 20	16	13.3
Mean nationality	22	18.3
Farm capacity		
Less than 25000	71	59.2
25001 – 50000	35	29.2
50001 – 75000	10	8.3
75001 – 100000	4	3.3

Table 1 shows social-demographic indicators of poultry farmers in Oyo State. As a finding, the majority (77.5%) of the poultry farmers sampled were between 26 and 55 years of age during the study, while 13.3% of respondents were aged 15-25 years, and a few (9.2%) were above 55 years of age. The number of male and female respondents was 70.8% and 29.2%, respectively.

In addition, just over half (50.8 %) of the poultry farmers were married, 35.8 % were single, 6.7 % were divorced, and 85.0 % of the respondents were of between primary to tertiary level education, with above 59.2 % of poultry farmers practicing the Islamic religion or 39.2 % of the poultry farmers practicing Christianity with mean years of experience of 15±7.57 years.

A total of 50.0% of the respondents had 6 to 20 staff members or workers, 31.7% had 1 to 5 staff members or workers, and 18.3% had more than 20 personnel. Regarding farm capacity, over half (59.2%) of the sampled respondents had a population of fewer than 25,000 poultry birds, and 29.2% had a population of 25,000-50,000 birds at the time of this study.

Table 2: Summary statistics of continuous variables of respondents (n = 120).

Variable	N	Mean	Std. Deviation
Age (years)	120	38.05	11.66
Sex	120	1.29	0.45
Marital status	120	1.96	0.94
Educational qualification	120	2.43	1.00
Religion	120	1.41	0.54
Tribe	120	1.28	0.81
Nationality	120	1.23	0.43
Years of poultry farming experience	120	11.48	7.05
Number of staff/workers	120	11.24	6.64
Farm capacity (birds)	120	26,458	18,920

Furthermore, as shown in Table 2, the summary statistics of the respondents indicate that the mean age was 38.05 years, with a standard deviation of 11.66, suggesting that the majority were middle-aged, with some spread across younger and older groups. The mean sex score was 1.29 (SD = 0.45), indicating that, based on the coding, most respondents identified as male. The average marital status was 1.96 (SD = 0.94), showing that the majority were married, although singles were also represented. For educational qualification, the mean of 2.43 (SD = 1.00) suggests that respondents on average had secondary education, with variations ranging from no formal education to tertiary level.

Religion had a mean score of 1.41 (SD = 0.54), indicating that most respondents identified as Muslims, while a considerable proportion identified as Christians. The mean tribal code was 1.28 (SD = 0.81), indicating that the Yoruba were the predominant ethnic group. The mean nationality of 1.23 (SD = 0.43) reflects that the majority were Nigerians, with foreigners forming a minority.

In terms of years of poultry farming experience, the mean was 11.48 years, with a standard deviation of 7.05, indicating substantial experience with considerable variation across respondents. The average number of staff employed was 11.24 (SD = 6.64), suggesting a workforce of small to medium-sized sizes with variability. Finally, the mean farm capacity was 26,458 birds with a standard deviation of 18,920, reflecting moderate production capacity overall but with considerable variation across farms, ranging from small to much larger operations.

Awareness And Source of Information About Salmonellosis Infection: -

Table 3: Awareness of Salmonella

Awareness of Salmonella	Yes (%)	No (%)
Have you heard of a disease called Salmonellosis	120 (100.0)	0(0.0)
Have you noticed any signs of Salmonella infection on your farm?	90(75.0)	30(25.0)
Are you aware of the incidence of Salmonella in your farm?	78(65.0)	42(35.0)
If not, are you aware of it in someone else's farms before? **(n = 42)**	33(78.6)	9 (21.4)
Are your farm workers/attendants aware of Salmonella?	66(55.0)	54(45.0)
If yes? Are they following all necessary protocols to prevent Salmonella contamination? **(n = 66)**	60(90.9)	6(9.1)

Table 3 reveals the awareness about Salmonella in Oyo State. Findings show that all (100.0 %) of the respondents have had Salmonellosis. The majority (90.0%) of the respondents reported that their staff were observing all necessary protocols to prevent the incidence of Salmonella infections. In comparison, the majority (78.6%) of respondents were aware of Salmonella from someone else's farm within Oyo State.

Additionally, the majority (75.0%) of respondents reported noticing signs of Salmonella spread on their farms, and 65.0% of them reported the presence of Salmonella in their poultry farms. Above half (55.0%) of the respondents were aware of Salmonella infection in the farms.

Source(S) Of Information About Salmonella Infection: -

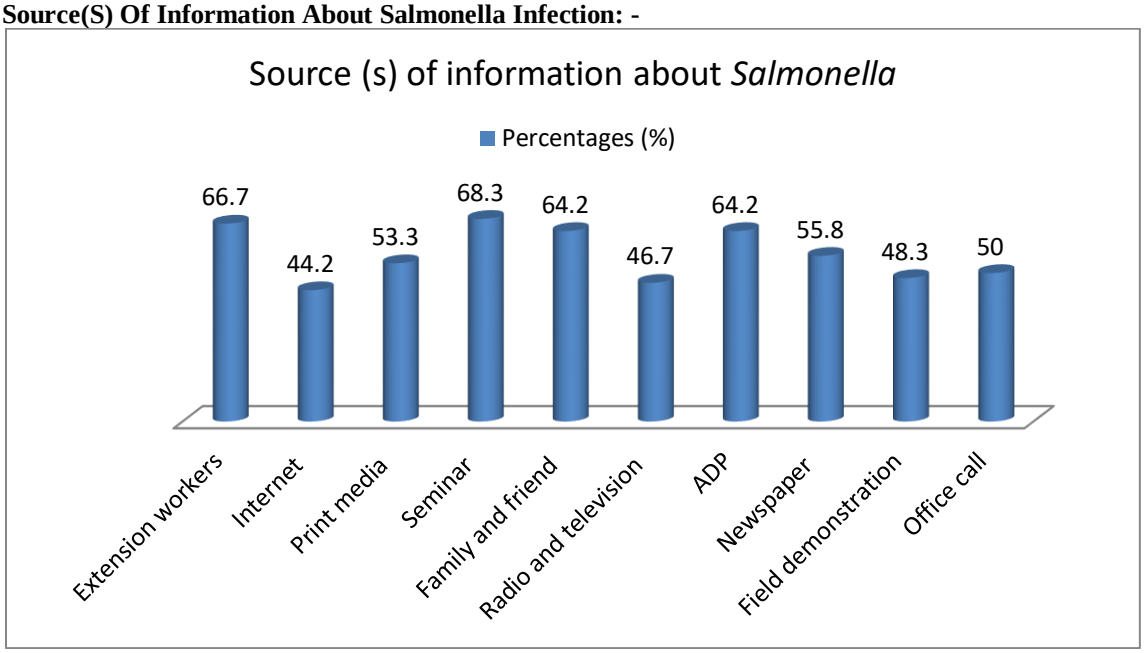

Figure 2:Source(s) of information about Salmonella in the study area.

Figure 2 reveals the source (s) of information about Salmonella infection, which is based on multiple responses from the respondents sampled. Findings show that the majority (68.3%) of respondents reported that Salmonella was sourced from the seminar. In comparison, 66.7% of respondents reported that Salmonella was sourced from the extension agent, and 64.2% stated that it was sourced from ADP and family/friends.

Other identified sources of information about Salmonella by the respondents were newspapers (55.8%), print media (53.3%), office calls (50.0%), field demonstrations (48.3%), radio and television (46.7%), and the internet (44.2%).

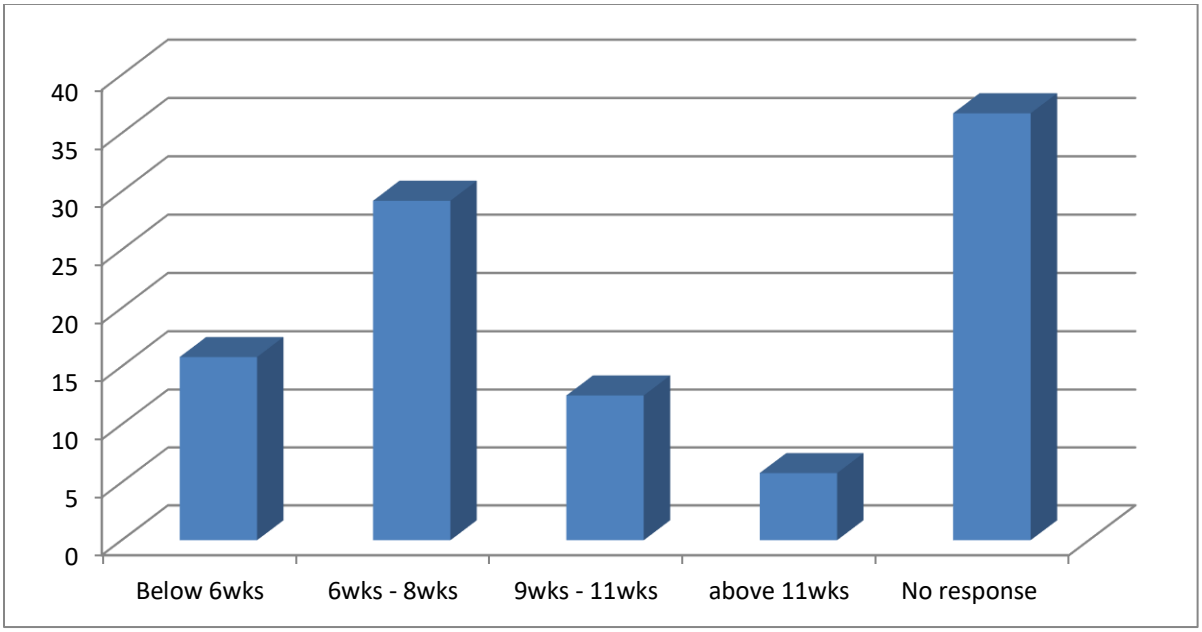

Figure 3: Age at which Salmonella was noticed by the respondents sampled.

Figure 3 reveals the age at which the respondents notice chicks with signs of Salmonella. Findings show that 36.7% of the respondents indicated they had no idea at what age they first noticed chicks with Salmonella infection in the study area at the time of this study. In comparison, 29.2% of the respondents report 6 weeks to 8 weeks, while 15.8% of them indicate less than 6 weeks. 12.5% of the respondents reveal 9 weeks – 11 weeks, and 5.8% of the respondents suggest above 11 weeks.

Knowledge Of Respondents About Salmonella Infection

Table 4: Knowledge of respondents about Salmonellosis

Knowledge	Yes (%)	No (%)
Keeping birds in proximity can cause these diseases	106(88.3)	14(11.7)
The source of stock is a means of transmitting the disease	59(49.2)	61(50.8)
A source of day-old food is another means of transmitting diseases	67(55.8)	53(44.2)
Visitors are asked to keep away from the pen house to prevent the spread of diseases.	61(50.8)	59(49.2)
Regular feed and water should be ensured to prevent diseases.	101(84.2)	19(15.8)
Vaccination of birds can prevent the spread of diseases.	78(65.0)	42(35.0)
There is a need for a declaration from the hen stock supplier stating that the chicks are free from the Salmonella organism.	65(54.2)	55(45.8)
Footbaths filled with treated water should be placed at the entrance of each pen.	63(52.5)	57(47.5)
There should be regular vehicle wheel washing to prevent the spread of disease	68(56.7)	52(43.3)
There is a need to wear personal protective equipment (PPE) during farm operations.	76(63.3)	44(36.7)
Wild animals, rodents, and birds must not have access to the pen and feed.	72(60.0)	48(40.0)

Table 4 reveals that the majority (88.3%) of the respondents were aware that keeping birds in proximity can cause these diseases in their poultry farms. In comparison, the majority (84.2%) of the respondents sampled also knew that regular feed and water should be ensured to prevent diseases in poultry farms, and 65.0% of the respondents believed and indicated that vaccination of birds can prevent the spread of Salmonella infection.

Furthermore, the majority (63.3%) of the respondents recognized the need to wear personal protective equipment during farm operations. Additionally, 60.0% of the respondents understood that wild animals, rodents, and birds must not have access to the pens and feed on farms. Above half (56.7%) of the respondents recognised that regular vehicle wheel washing is necessary to prevent the spread of Salmonella infections in poultry farms, and 55.8% of the respondents also understood that the source of day-old chicks is another means of transmitting Salmonella infections

Other notable understanding by the respondents was that there is a need for declaration from the hen stock supplier that chicks are free of Salmonella (54.2 %), footbaths filled with treated water should be placed at the entrance of each pen (52.5 %) and visitors need to be keep away from the pen house to avoid the spread of diseases (50.8 %). Moreover, knowledge about Salmonella disease was recorded as average, and measures to improve it must be implemented by the respondents sampled in Oyo State, as this will safeguard the farm from unnecessary diseases that may arise.

Management and prevention of Salmonella infection

Table 5: Management of Salmonella infection

Management of Salmonella infection	Always	Occasionally	Never	Mean
Biosecurity practices (Prevention)				
A poultry farm must be far from public roads	41(34.2)	52(43.3)	27(22.5)	2.12
Poultry farms and pens must be at least 100 feet apart from one another	38(31.7)	48(40.0)	34(28.3)	2.03
A poultry farm must not be located within the lake or	41(34.2)	55(45.8)	24(20.0)	2.14

pond				
The poultry pen must have a gate that restricts vehicle access to the farm	25(20.8)	44(36.7)	51(42.5)	1.78
The Poultry farm must be well-fenced	35(29.2)	40(33.3)	45(37.5)	1.92
Rodents must be checked on the farm to minimize the level	33(27.5)	53(44.2)	34(28.3)	1.99
The surroundings of the poultry farm must be weeded and avoid bushy areas	28(23.3)	58(48.3)	34(28.3)	1.95
Other livestock must be controlled to at least 60m from the poultry house	28(23.3)	60(50.0)	32(26.7)	1.97
Poultry litter should be taken to the poultry house	22(18.3)	53(43.3)	46(38.3)	1.80
Each pen should have a separate shoe, cap, boot, cloth, etc., to wear during operation and activities	25(20.8)	68(56.7)	27(22.5)	1.98
All materials used should be regularly cleaned and always disinfected	34(28.3)	68(56.7)	18(15.0)	2.13
The disinfectant at the entrance of each poultry house must be ensured	22(18.3)	55(45.8)	43(35.8)	1.83
There should be multiple age groups of birds on the farms	27(22.5)	52(43.3)	41(34.2)	1.88
Medication (prevention and control)				
Birds should be vaccinated for agents known to have caused problems on the farm in the past	59(49.2)	39(32.5)	22(18.3)	2.31
Adequate vaccination of day-old birds should be done at the hatchery	45(37.5)	51(42.5)	24(20.0)	2.18
Application of the Immucox vaccine at 1-5 days	47(39.2)	52(43.3)	21(17.5)	2.22
Application of the Marek vaccine at 1 day old	54(45.0)	41(34.2)	25(20.8)	2.24
Newcastle disease vaccine at one day old chicks must be given	37(30.8)	45(37.5)	38(31.7)	1.99
Vaccination of 1st Gumboro vaccine at 8 – 10 days and 2nd at 1 week after	41(34.2)	61(50.8)	18(15.0)	2.19
Application of Newcastle disease vaccine Lasota at the 2nd and 5th week	44(36.7)	44(36.7)	32(26.7)	2.10
Vaccination against Fowl pox at 8 weeks	46(38.3)	44(36.7)	30(25.0)	2.13
Application of Newcastle disease vaccine Komorov at 12 weeks	36(30.0)	55(45.8)	29(24.2)	2.06
Routine use of NDV Lasota every month should be done	48(40.0)	42(35.0)	30(25.0)	2.15
Timely interval of routine deworming	46(38.3)	47(39.2)	27(22.5)	2.16
Timely interval of routine application of antibiotics	39(32.5)	59(49.2)	22(18.3)	2.14
Delousing birds must be done	36(30.0)	52(43.3)	32(26.7)	2.03
Frequency of contact with the veterinary doctor	43(35.8)	52(43.3)	25(20.8)	2.15
Regular examination of sick or dead birds	39(32.5)	54(45.0)	27(22.5)	2.10
Insurance of poultry farm (mitigation)	37(30.8)	56(46.7)	27(22.5)	2.08

Table 5 reveals the management and prevention of Salmonella infection in the study area. The findings indicate that the mean value of bio-security practices is that poultry farms should not be located near lakes or ponds, with a mean value of 2.14. At the same time, each material used should be regularly cleaned and always disinfected (= 2.13), poultry farms must be a distance from public roads (= 2.12), and poultry farms and pens must be a distance from one another (= 2.02) in the study area.

Furthermore, rodent must be control in the farm to minimize level (= 1.99), each pen should have a separated shoe, cap, boot, cloth etc., to wear during operation and activities (= 1.98), also other livestock animal aside poultry must be control to at least 60 m to poultry house (= 1.97) and poultry farm surrounding must be weeded and avoid bushy (= 1.95).

Biosecurity practices are routine management strategies designed to prevent disease outbreaks and unforeseen problems on poultry farms. These measures are readily implemented by farmers at a low cost, unlike medication, vaccination, and insurance, which involve higher expenses.

The study's findings also highlight key vaccination protocols considered necessary by the respondents for preventing and controlling the spread of Salmonella. These include vaccinating birds against diseases previously encountered on the farm (= 2.31), administering the Marek vaccine on day one (= 2.24), applying the Immucox vaccine within the first 1–5 days (= 2.22), giving the first Gumboro vaccine at 8–10 days followed by a second dose a week later (= 2.19), and ensuring proper vaccination of day-old chicks at the hatchery (= 2.18).

Other notable prevention measures were a timely interval of routine de-worming (= 2.16), routine use of NDV Lasota every month, frequency of contact with the veterinary doctor (= 2.15), respectively, a timely interval of routine application of antibiotics (= 2.14), and vaccination against Fowl pox at 8 weeks (= 2.13) as prevention and control against Salmonellosis disease. This will minimize and prevent the occurrence of disease in the farms.

NB: The biosecurity measures listed (cleaning, disinfection, rodent control, restricted access, farm spacing, protective clothing, and weed control) directly prevent Salmonella. The vaccinations, deworming, and veterinary checks primarily prevent other diseases, but they also indirectly help by maintaining the birds' strong immunity, which reduces the chances of Salmonella colonization and spread.

Categorization of management of Salmonella infection

The management of poultry diseases, particularly Salmonella, was classified into three categories: (1) Low level (0.00–0.33), (2) Moderate level (0.34–0.66), and (3) High level (0.67–1.00). According to Table 5, most poultry farmers (62.5%) fall within the low-level management category, 25.0% practice moderate-level management, and 12.5% operate at a high level (Table 6).

Table 6: Distribution of the level of poultry disease management (i.e, Salmonella spp. widespread)

Poultry diseases	Management level	Frequency	Percentages (%)
Low	0.0 – 0.33	75	62.5
Moderate	0.34 – 0.66	30	25.0
High	0.67 – 1.0	15	12.5
Total		**120**	**100.0**

Strategies implemented for controlling Salmonella infection widespread in the poultry farm and the environment

It was shown that 80.0% of the respondents indicated regular hand washing as a good strategy to control Salmonellosis disease. In comparison,75.9% of the respondents sampled also suggest that proper preparation of poultry feed is a good strategy to implement in controlling Salmonellosis in poultry farms. 68.3% of the respondents believe and indicate that a good water source can prevent the spread of Salmonella infection if implemented. Furthermore, 65.0 % of the respondents indicate that regular vaccination of birds and the environment is a good strategy to be implemented in controlling Salmonellosis disease, 64.2% of them suggest that general cleaning of the farm environment, and 63.3% of them also indicate that personal (body) hygiene is a good strategy to be implemented in controlling Salmonellosis. Others included proper waste disposal, regular screening of visitors to farms, reporting sick birds to the veterinary clinic, and appropriate monitoring and evaluation of poultry farms (Table 7).

Table 7: Strategies implemented in controlling Salmonella in the poultry farm and environment.

Preventive and control measures of Salmonella infection by the respondents	Yes (%)	No (%)
Regular hand washing	96(80.0)	24(20.0)
Personal (body) hygiene	76(63.3)	44(36.7)
Reporting to the veterinary clinic when birds are sick	69(57.5)	51(42.5)
Good water source	82(68.3)	38(31.7)
Proper preparation of poultry feed	91(75.8)	29(24.2)

Regular screening of people visiting the farm	71(59.2)	49(40.8)
General cleaning of the farm environment	77(64.2)	43(35.8)
Regular vaccination of birds and the environment	78(65.0)	42(35.0)
Proper monitoring and evaluation of farms	60(50.0)	60(50.0)
Proper disposal of waste	72(60.0)	48(40.0)

Several influences the Level of Poultry Disease Management:-

The overall adequacy of the model was confirmed using the Chi-square test, which was statistically significant at the 1 % level (χ^2 = 102.45, p = 0.0001), indicating a strong fit for the data. The marginal effects analysis revealed several key factors influencing poultry disease management levels among farmers. The sex of the respondent had a notable impact; female poultry farmers were 21 % less likely to achieve a moderate level of disease management compared to their male counterparts. This suggests that female farmers are less likely to implement moderate disease control practices. Education was found to have a positive relationship with disease management.

For each additional year of formal education, the probability of attaining a moderate level of disease control increased by 1 % compared to a low level. This implies that higher educational attainment enhances the likelihood of adopting effective and modern disease management practices. Moreover, the household size also played a significant role, with an increase in household members associated with a 13% rise in the probability of achieving moderate disease management. Similarly, each additional year of poultry farming experience increased the likelihood of moderate disease control by 2%. These findings are consistent with the study by Ezeh et al. (2012), which suggested that more farming experience enhances a farmer's ability to manage disease outbreaks effectively.

Furthermore, marital status was found to increase the likelihood of achieving moderate disease management by 11%. Additionally, the farmer's nationality and ethnic background (tribe) increased the chances of achieving a moderate level of disease control by 23% and 25%, respectively. Farmers who are Yoruba-speaking natives of the study area were more likely to possess better knowledge and practices for disease prevention compared to non-natives. Farm capacity was also a significant predictor; larger-scale operations had a 21 % higher likelihood of achieving moderate disease management compared to smaller farms.

Being female slightly reduced the probability by 2%, while a larger household size increased it by 6%. An additional year of farming marginally raised the likelihood of high-level disease control by 0.3%. Moreover, both nationality and farm capacity contributed to a 10% increase in the possibility of achieving a high level of disease management compared to a low level.

Table 8: Results of the multinomial logit model of determinants of the level of poultry disease management

Explanatory variables	Marginal effect	Std. Error	T-value	Marginal effect	Std. Error	T-value
Age	-0.3421	0.2151	-0.453	-0.1261	0.3971	-1.602
Sex	-0.2159**	2.1412	-2.326	-0.0264**	0.1127	-0.167
Educational level	0.0148**	0.3823	1.324	0.0072	0.0013	0.079
Household size	0.1356**	0.2814	0.874	0.0643*	0.0112	1.178
Hired labour	-0.0003	0.0453	-0.321	0.0732	0.0033	2.187
Poultry farm experience	0.0244*	0.1417	0.645	0.0033**	0.0132	0.433
Marital status	0.1102**	0.3216	2.254	0.1224	0.0094	1.704
Nationality	0.2373*	0.5365	1.382	-0.1017*	0.1014	-1.346
Tribe	-0.2564**	0.1563	0.237	0.0429	0.1142	0.355
Poultry system	0.2026	0.4212	0.443	- 0.1627	0.0624	-1.052
Farm capacity	0.2138**	0.1021	-0.253	0.1008*	0.3121	0.353
Age of birds	0.0023	0.0641	0.243	0.0023	0.0124	0.178
Mortality rate (%)	0.2543	0.1034	1.462	0.0033	0.0157	0.135

*Significant at 10%, **Significant at 5%, ***Significant at 1%, No. Of obs = 120 LR χ^2 = 102.45 Prob>χ^2 = 0.0001, Log likelihood = -112.2302 Pseudo R^2 = 0.1014.

Discussion: -

Most of the poultry farmers surveyed were within their economically active age group. They were relatively young, making them more likely to adopt innovations that could enhance poultry production in Oyo State, Nigeria. The outcome suggested that contemporary poultry farming remains a male-dominated profession rather than a female-dominated occupation, likely due to the nature of the risks involved, as well as the labour-intensive nature of farm husbandry, which is not favourable to most women.

This finding aligns with earlier studies by Lawal et al. (2009), Adisa and Akinwumi (2012), and Uzokwe and Bakare (2013). Nevertheless, 35.8% of the participants were still unmarried, with 85% having a formal education. In terms of worshipped religions, Islam and Christianity are the most dominant, as 77.5% of the sampled respondents are Nigerians. Most of the poultry farmers (83.4%) were experienced in poultry farming, with a maturity of 1-17 years. This is anticipated to contribute to improved disease management, as greater years of experience in poultry farming generally equip farmers with better exposure and skills, making them more effective in preventing and managing poultry diseases.

The present study's findings indicate that insecure practices of disease prevention made a significant relative contribution to disease management, compared to the use of medications and insurance. However, this is because bio-security practices are standard business practices that poultry farmers can easily implement, which do not incur high costs compared to medication and insurance. This observation contradicts the results obtained by Obi et al. (2008), who found that poultry production in Nigeria is primarily characterized by backyard poultry production, which is often associated with insignificant or no biosecurity, as opposed to the minimal or moderate biosecurity observed in peri-urban and urban commercial poultry production. The respondents' knowledge of salmonellosis was evaluated through their awareness of its prevention and control measures in poultry farms, as well as their ability to recognize the symptoms of the disease. In most cases, it became evident that salmonellosis diseases are unfamiliar to most farm handlers.

This could be attributed to their low level of education and exposure to related issues, which indicates a lack of awareness of the disease (Agada et al., 2014). This, nevertheless, could have been due to the high rate of prevalence that some poultry farms had been reported to have. In addition, the lack of knowledge has also increased the risk of exposure and transmission of Salmonella from farm handlers to flocks, as reported by several studies (Charles and Takayuki, 2010; Mai et al., 2013), especially with the recent surge in poultry farming business in Jos. Salmonellosis is considered one of the most significant bacterial disease challenges facing the global poultry industry. Salmonella species are responsible for a variety of acute and chronic diseases in both poultry and humans (Majowicz et al., 2010; Okworiet al., 2013).

Infected poultry products are among the most significant sources of foodborne outbreaks in humans. Our study revealed that the hygienic practices of poultry farmers did not meet the hygiene standards for handling meat products as recommended by the World Health Organization and the Food and Agriculture Organization Joint Committee (Codex Alimentarius Commission, 2005). Poultry feed accounts for the most significant proportion of production costs in both Oyo State and Nigeria as a whole. The food is commonly mixed with animal constituents, such as eggshells, blood meals, fish meals, and bone meals. Soybean cake and groundnut cake, which are plant-based sources of protein and calcium, are commonly used in animal feed.

However, improper preservation, storage, and packaging of these ingredients often lead to contamination risks in poultry feed. As noted by Jones and Richardson (2004), Nigeria's climatic conditions are characterized by warm and humid weather. Under these circumstances, Salmonella organisms can multiply in feed, particularly during storage and administration on farms. Importantly, contamination can also occur during the processing, transportation, and distribution of poultry feed. To reduce costs, many farmers either prepare feed themselves on the same premises where birds are kept or source it from local feed mills with poor hygiene standards. These practices heighten the risk of disease outbreaks. This high variety of ingredients used to produce poultry feed, as well as the high level of diversification among the farms in the feed production and processing, and the general low level of hygienic practices, can explain the high prevalence of Salmonella in feed samples and the heterogeneity of serovars isolated from this source (Fagbamila et al., 2017).

The outcome of this research has shown that the importance of bio-security practice (disease prevention) by poultry farmers in disease management is ranked very close to medication and insurance within the study region. This

actually shows that bio-security measures are an everyday managerial practice that is readily practised by poultry farmers at a minimum cost, compared to medication and insurance, which require a high price. The application of standard biosecurity measures is crucial in protecting poultry birds from diseases, as demonstrated by Dorea et al. (2010). However, biosecurity has focused on maintaining or improving the health status of animals and preventing the introduction of new disease pathogens by assessing all possible risks to animal health (Fraser et al., 2010; Julien and Thomson, 2011). Augustine et al. (2010) reported that the implementation of sound biosecurity measures will go a long way in minimizing the problems of disease outbreaks and spread in the Nigerian poultry industry, while also maintaining consumers' confidence in Nigerian poultry products.

Nevertheless, evidence gathered showed that there is a diverse urgency to sensitise the poultry farmers on the need to adopt good hygienic practices and sanitary measures to contain the spread of Salmonella. Aside from resource constraints, several measures are suggested to limit vertical and horizontal transmissions of Salmonella on farms and make the birds less vulnerable to Salmonella, as noted by some scholars (Humphrey, 2006; Wales et al., 2007; Ishihara et al., 2009). Specifically, to ensure feed and water remain free from Salmonella contamination, farms must implement effective cleaning and disinfection practices, establish strong protective measures against both inanimate and animate vectors, and enhance the overall hygiene and sanitary conditions of the poultry environment.

The findings from Oyo State align with trends reported in other parts of Nigeria and West Africa, underscoring the regional significance of Salmonella as a persistent challenge in poultry farming. For example, studies in Plateau State (Agada et al., 2014) and Kaduna State (Mamman et al., 2014) also reported high prevalence of Salmonella and emphasized weak biosecurity practices as critical risk factors. Similarly, investigations in Kwara State (Ahmed et al., 2017) documented the widespread presence of virulence genes in poultry-associated Salmonella isolates, reinforcing the urgent need for robust control measures.

Comparable issues have been highlighted in Ghana and Ethiopia, where poor hygienic conditions, inadequate vaccination, and weak extension services were linked to the spread of Salmonella and other poultry pathogens (Bettridge et al., 2014). These consistencies across states and neighbouring countries demonstrate that the challenge of Salmonella management in Oyo State is not isolated but part of a broader regional pattern that requires coordinated interventions, policy harmonization, and strengthened farmer education to safeguard poultry production and public health.

Vaccination plays a vital role in poultry health management, not only for controlling specific diseases but also for strengthening the overall immunity of the flock, thereby indirectly reducing susceptibility to Salmonella infections. Each vaccine targets a particular pathogen, and its proper administration ensures that poultry remain healthy and productive. The Marek vaccine, administered on the first day of life, protects chickens against Marek's disease, a viral condition that can cause paralysis, tumours, and severe immune suppression. Preventing this disease ensures that the birds maintain strong immune systems, enabling them to resist other infections, including Salmonella, more effectively.

Similarly, the Immucox vaccine, given within the first one to five days, prevents coccidiosis, a parasitic intestinal disease. By protecting the gut from damage caused by coccidia, this vaccine helps to maintain intestinal integrity, making it more difficult for pathogens like Salmonella to establish and persist. The Gumboro vaccine, also known as the Infectious Bursal Disease (IBD) vaccine, is administered between 8 and 10 days of age and repeated a week later. Its primary role is to protect the bursa of Fabricius, an essential immune organ in poultry, from viral destruction.

A healthy immune system is critical for resisting bacterial infections such as Salmonella, which often exploit immunosuppressed birds. Additionally, the NDV Lasota vaccine, administered monthly, protects against Newcastle disease, a highly contagious viral illness that can affect the respiratory, digestive, and nervous systems of poultry. Preventing Newcastle disease helps reduce stress and secondary infections, creating a healthier flock that is less vulnerable to bacterial colonization.

Finally, the Fowlpox vaccine, administered around eight weeks of age, prevents fowlpox, a viral disease that causes lesions on the skin, mouth, and upper respiratory tract. While this disease is not directly related to Salmonella, vaccination reduces overall disease pressure and stress, thereby contributing indirectly to better flock health and resilience. In summary, although none of these vaccines directly target Salmonella, they are crucial in building the

birds' immune defences and protecting them from other debilitating diseases. By keeping the flock healthy, these vaccination protocols indirectly reduce the likelihood of Salmonella infection and its spread, making them an essential part of an integrated disease prevention strategy on poultry farms.

Conclusion: -

The outcome of this research indicates that the poultry farming industry is predominantly male, and the farmers were active, agile, and within the productive age range; they were well-educated, with significant formal education, and possessed considerable experience in poultry farming. Moreover, the study populations demonstrated a high awareness of salmonellosis disease, including its signs, symptoms, past occurrences, and preventive measures. In addition, key information sources for Salmonellosis disease were identified as seminars, extension workers, family/friends, and the Agricultural Development Programme (ADP), with most study participants being well-informed about disease prevention.

However, the findings suggest that biosecurity practices have a significant influence on poultry disease management in Oyo State, Nigeria. Nevertheless, most farmers practised low levels of disease management, with only a minority achieving moderate or high levels. Positive factors associated with mild disease management, compared to low levels, included years of formal education, household size, and poultry farming experience, whereas the farmer's sex had a notable adverse effect. In addition, marital status, nationality, tribe, and farm capacity were significant determinants of disease management levels.

Recommendations: -

Considering the study's findings, the following recommendations are suggested: -

1. The point of policy focus must be directed towards the enlightenment programmers on the importance of biosecurity as an essential aspect of managing poultry disease within the study region, or indeed to the whole country.
2. It should be required that the extension agency spread better bio-security measures and better medication methods to all poultry farmers, which will enhance the current level of poultry disease control in the study area.
3. Furthermore, it is stipulated that the government ought to educate poultry farmers regularly with reference to biosecurity, disease reactions, and integration of current husbandry-grazing practices, which will protect our livestock sector.
4. Poultry farmers in the southwest of Nigeria have a very low mitigation option, utilizing a livestock insurance policy. Consequently, the government should implement a policy that increases subsidies on livestock insurance to make it more affordable for poultry farmers.
5. Lastly, educating poultry farmers and raising awareness about the advantages of livestock insurance through extension agents is vital to boost their engagement in using insurance as a tool to manage the risks associated with disease outbreaks in poultry farming.

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